HEALTH RISK DIFFERENTIALS: IMPLICATIONS OF NEIGHBORHOOD CONDITIONS ON VARIOUS HEALTH OUTCOMES IN NEW ORLEANS, 2004-2009

BY

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DISSERTATION

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ABSTRACT

This dissertation examines the effects of neighborhood conditions on health outcomes in New Orleans pre- and post-hurricane Katrina, an important topic in the context of community recovery following a disaster event. This dissertation follows the "three chapter (paper) journal format". The first paper (Chapter 2) examines hot spots for unattended swimming pools and associated neighborhood predictors from 2006 to 2009, a period during which the city experienced widespread devastation from hurricanes Katrina and Rita. A surfeit of unattended pools on properties abandoned by displaced residents has a number of potential direct and indirect negative health impacts for returning local residents including elevated transmission rates due to a punctuated increase in the relative abundance of mosquito breeding sites.

Based upon the *Broken Windows theory*, spatial variables describing physical and socioeconomic neighborhood characteristics hypothesized to influence the density of unattended pools in the study area were identified to answer the following core research questions: 1) what is the spatial structure of unattended pools over time during post-Katrina New Orleans? 2) What neighborhood predictors are associated with this variability? 3) How do demographic characteristics and neighborhood structural deterioration affect the odds of a pool being unattended in 2006 immediately after Katrina compared to the longer period from 2006 to 2008 when recovery dynamics may reflect more than the physical effects of the hurricane. The results indicate that traditional variables associated with neighborhood deterioration (e.g. vacant houses, properties with major structural damages); do not provide as robust an explanation for presence of unattended pools in study area. This suggests that it may be more of the effect of neighborhood demographics and underlying preexisting characteristics of neighborhood

conditions influencing unattended pool presence rather than the physical deterioration of neighborhoods of which unmaintained pools contribute.

The second paper (Chapter 3) is an observational study whose aim is to identify neighborhood and socio-demographic factors associated with changes in mental health disorders in New Orleans, Louisiana for three time points (2004, 2008 and 2009). In addition, this study examines the extent to which the rate of hospitalization varies across individual characteristics such as gender, race, marital status and income. Cases include all hospital admissions reported to the Louisiana Department of Health and Hospitals' database but exclude military and veteran administration hospitals. Predictor and explanatory (patient data) variables were first geocoded and aggregated to the block group using geographical information systems (GIS) ArcGIS 9.3 software. Logistic regression was used to explore the relationship between predictor and outcome variables. Results indicate that (1) the hospitalization rates of mood and anxiety and psychosomatic disorders have decreased over time. The rate in 2008 was higher than that in 2004(for mood and anxiety and for psychosomatic disorders (P=0.000), (2) No statistically significant change was observed in substance abuse hospitalizations over time. (3) Protective factors for mental health disorders included recovery factors and population white. (4) Risk factors include neighborhood decay variables and demographic characteristics. More men than women were admitted overall. Gender, race, marital status and income affected how patients received treatment for stress-related mental disorders.

In the third paper (Chapter 4) I correlate temporal and spatial changes in mosquito abundance with neighborhood, socio-demographic, and land cover factors (2006 to 2010) with *Culex(Cx.) quinquefasciatus* species abundance. Neighborhood and socio-demographic covariates recorded for each trap location included abandoned swimming pools, imminent health

threat listed properties, public nuisance property listings, completed property demolitions, population, household income and number of households and a disaster impact variable water depth. Both spatial (GIS and remote sensing) and non-spatial techniques (logistic regression) are used. Predictors of *Cx. quinquefasciatus* species abundance in New Orleans include land cover variables, temperature, large water bodies and highly developed areas, and a neighborhood variable or completed property demolitions. The findings of this study suggest that land cover and neighborhood characteristics predict mosquito abundance in the study area more than socio-demographic characteristics. The current findings add to a growing body of literature on vector-borne disease risk associated with disasters. The findings of this chapter have a number of important implications for mosquito control programs and supports earlier research findings that vector-borne disease risks increase rapidly post-disaster representing a greater public health threat.

For my mother Susan Mwansa and my children,

Vanji and Maila Lwipa Moise,

for always believing in me

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CHAPTER 1

INTRODUCTION

When hurricane Katrina struck the gulf coast on August 29, 2005**,** it caused massive devastation to many of the poorest cities in the country. The greatest impact, by far, WAS felt in the city of New Orleans, where flooding displaced more than one million people and caused significant devastation to both the psychosocial and material infrastructure. The hurricane and its aftermath have produced an urban landscape dotted with an expanded number of imminent health threats including property listings, public nuisance and blighted properties, some with abandoned and unattended swimming pools. The city is also characterized by a lack of services, a diminished workforce, unprecedented mental health needs, economic challenges, cumbersome political decision making, slow implementation, and a shortage of health care professionals whom themselves have been displaced, traumatized, and overworked (Berggren and Curiel 2006; Voelker 2006; Weisler et al. 2006).

Much of the post disaster research that focuses on explaining the consequences of hurricane Katrina on residents that experienced the disaster has been conducted both at the individual and neighborhood level: examining both short and long term health and human risk impacts on residents. Recently more work has related hurricane Katrina to depression, Katrina-related psychological stress, vector pathogen risk, and exposure to contaminants (Caillouet et al. 2008; McLaughlin et al. 2009; Picou and Hudson 2010; Rhodes et al. 2010; Tees et al. 2010 Zahran et al. 2010). However, this work has been limited to either one neighborhood or a small number of census tracts in a defined geographical neighborhood and has relied heavily on surveys and interviews conducted using small community samples and/ or convenience samples

(Kim et al. 2008; Roberts et al. 2010; Olteanu et al. 2011). This project expands prior work by examining Katrina related-health risks across New Orleans (here considered as the 478 New Orleans block groups), using pre- and post-disaster data collected for running local government. Non-spatial and geospatial techniques are used to examine how proximal neighborhood structural conditions, socio-demographic and recovery variables relate to stress-related mental disorders and vector-borne disease risk.

In the chapters that follow, I study mechanisms by which specific relevant neighborhood variables influence psychological well-being and disease risk transmission in the New Orleans landscape pre- and post-hurricane Katrina. This study is inspired, in part, by three theories; the *broken windows* thesis, the social disorganization perspective and the ecological perspective (environmental stress). The Broken Windows thesis and the Social Disorganization perspective are sociological and criminological ways of thinking. These theories are influenced theoretically by an understanding that wider neighborhood decay leads to physical disorder and negative health outcomes for both individuals and communities. I have used these theories based on a belief that they illuminate parallels between past and current health impacts resulting from changing neighborhood environmental and structural conditions, and reveal contradictions, misrepresentations, or potential long-term neighborhood health risks that might arise, directly or indirectly immediately and years following the hurricane. A focus on building a research agenda using both non-spatial and spatial statistical approaches has been another motivation.

Compared to previous research studies in the study area (McLaughlin et al. 2010, Rhodes et al. 2010); I have undertaken a measurement and analysis at a finer spatial and temporal scale. In the course of that analysis, I build and incorporate fine-grained spatial variables related to the natural, built and socio-demographic conditions of neighborhoods, which are used through the dissertation and provides a measure of neighborhood context, which is incorporated in testing the spatial and temporal variation in health outcomes including disease risk.

The remainder of this chapter outlines the theoretical contexts upon which this research builds and provides a conceptual overview and diagram of the dissertation. The dissertation follows a three-paper journal format, with the first paper following as chapter 2. By measuring the spatial structure of unattended swimming pools over time during post-Katrina years and by examining the degree to which this structure description defines neighborhoods of persistent problems compared to those that improved, this paper not only introduces background information but sets up the problem areas for chapters 3 and 4. The logic is quite intuitive. The identified relevant neighborhood physical structural and socio-demographic variables of the study area provide covariates used to evaluate the significance of each variable in the spatial distribution of stress-related mental disorders and in assessing predictors for adult mosquito vector abundance.

Chapter three examines the extent to which three mental disorders (mood and anxiety, psychosomatic and substance abuse) relate to neighborhood physical structural conditions, socio-demographic characteristics and to the August 29th, disaster for years 2004, 2008 and 2009. Chapter four assesses the abundance and distribution of *Cx. Quinquefasciatus*, the primary vector for West Nile virus (WNV). The last chapter (chapter 5) focuses on the discussion of the work presented in the previous chapters and concludes the dissertation.

1.1 Theoretical Context of the Research

This dissertation is theoretically informed by several related literatures that form a compelling interdisciplinary intersection: studies of sociology, urban ecology and health geography. The dissertation draws from recent inquiries in these literatures, contributing materially or theoretically to each of the three papers that move from the ecological, to connecting the physical environment with social conditions and health outcomes, to the assessment of vector mosquito abundance that allow me to take advantage of the ability of geospatial tools to parse out effects at each level of analysis. Specific attention will be given to the literature that focuses on neighborhood context and health. In this section, I will summarize the relevant research agendas of each theory used in the analyses with the theory specific to the relevant mechanisms by which features within the immediate neighborhood context influence health outcomes studied in the dissertation given in each substantive chapter.

1.2 The Urban Ecological Perspective

Urban ecology is an emerging integrative science that utilizes an ecological perspective to not only assesses the interaction of biological and physical environmental features in an urban or urbanized community but also built and social components (Dow 2000; Pickett et al. 2008). However, what constitutes an urban ecosystem remains undefined or is defined differently by different people depending on their perspectives. For example, the general tendency is to describe urban ecosystems as human-dominated ecosystems used primarily for dwelling, however, this definition in itself is problematic as it does not account fully for an areas' history of development, its influence and potential impacts (McIntyre et al. 2008). On the other hand, for the ecologist, the urban ecosystem is an ecological conceptualization of the urban area or a conglomeration of interconnected systems with humans often considered as agents of disturbance whereas for urban geographers, an urban ecosystem is a place where processes of spatial growth and development occur (Carey 1970).

Nevertheless, it's unquestionable by both ecologists and social scientists that urban ecosystems are complex interconnected mosaics composed of discrete urban spaces, that are constantly being altered by human activities (Vitousek and Matson 1991; McDonnell et al. 1997; Dow 2000; Western 2001), and that any change, in turn, impacts the quality of urban life, fragments human relationships, increases disease risk and morbidity, and diminishes income and social stability (Park and Burgess 1925; Kruger 2008; Patz et al. 2004). Research on physical environmental impacts on health outcomes and effects of the environment on the emergence or reemergence of infectious diseases has been conducted using different urban gradient approaches: biophysical variables (i.e. environment - patches, physical location of places and vegetation) and human components (i.e. social processes, economic development, landscape features- roads, dams, parks, stores etc., and land use and land management efforts as well as on a social historical context). The present research project explores the biophysical variables defining the urban gradient in New Orleans by using land cover and vegetation, including landscape features such as number of completed property demolitions, imminent health threat properties listings and unattended swimming pools to delineate disease risk.

1.3 Neighborhood-Oriented Models

Social disorganization or the disorder perspective

Social disorganization or the disorder perspective refers to the failure of communal institutions or organizations in certain neighborhoods and the inability of local residents to realize common goals as well as solve chronic problems (Bursik 1988; Sampson and Groves 1989; Bursik and Grasmick 1993). It focuses on the dynamic and effects of "kinds of places" or different types of neighborhoods in creating conditions favorable or unfavorable to a wider neighborhood disorder (Bursik and Grasmick 1993; Sampson and Raudenbush 1997). The idea is that the physical disorder in the environment can influence residents' perceptions about their neighborhood environment as more stressful.

Central to the social disorganization theory is the collective efficacy model (Shaw and McKay 1972; Sampson and Raudenbush 1997). Collective efficacy models link key aspects of urban neighborhood structure with variability in dimensions of social organization, which may be applied to the study of health with good effect. For example, Cagney and Browning (2004) show that high level of collective efficacy relate to lower rates of asthma and breathing problems in the Chicago metropolitan area. The researchers also show that the concentration of older houses relates positively to unhealthful environments (Cagney and Browning 2004). They theorized that high levels of collective efficacy facilitate social control which then affects neighborhood health behaviors and outcomes (i.e. the onset of asthma i.e. smoking), access to health care, psychosocial processes and the management of neighborhood physical hazards. In this study, collective efficacy is employed to explore the extent to which widespread neighborhood socioeconomic disadvantage and persistent deteriorating neighborhood conditions limit the availability of economic and social resources that are vital to sustain and expedite neighborhood recovery.

This study also expands previous ecological studies by incorporating the social and historical processes that have shaped the ecological conditions of such a mosaic in New Orleans, along with processes identified within social disorganization. For example, collective efficacy may be a protective factor because of the strong and consistent negative relationships it has with health outcomes and premature mortality. However, because main effects are hypothesized, the term resource will be used along with risk instead of the terms protection and protective factor. Neighborhood resources, then, describe more broadly material or infrastructural resources or as was introduced by Macintyre and colleagues “opportunity structures, which are socially constructed and socially patterned features of the physical and social environment which promote or damage health either directly, or indirectly through the opportunities they provide for people to live healthy lives" (Macintyre et al. 2002, pg. 130). It is hypothesized that neighborhood resources (e.g. well-maintained neighborhood physical features) will relate negatively to health outcomes whereas neighborhood physical disorder will relate positively, to neighborhood residents health and disease risk.

The Broken Windows Thesis

Another theory, which connects the physical environment with social disorder, is the "Broken Windows" theory (Wilson and Kelling 1982). The broken windows theory posits that minor forms of public disorder can lead to wider neighborhood problems if not mitigated. Certainly, according to this theory, the physical disorder in the environment, like litter, abandoned cars and houses, decaying buildings, and, yes, broken windows can serve as cues for people to violate social norms and to break a window too, thus broken windows should never be tolerated. There are at least three categories in which neighborhood characteristics typically impact health of residents: the physical environment (composed of the "built environment" constructed by people, as well as the natural environment such as parks or walkways), the social environment (resulting from individual behavior and the quality of social ties between residents), and the service environment (e.g. community resources- schools, hospitals, and recreation). In general, the evidence demonstrates that poor neighborhood conditions relate to poor health outcomes, but there is variability depending on the specific health outcome under study (Macintyre et al. 2002; Morland et al. 2002; Diez Roux and Mair 2010).

In the study area, the link between the hurricane disaster impact and socio-economic risk factors has been established. Previous research relates poverty, home ownership, poor English language proficiency, ethnic minorities, and proximity to the disaster and high-density housing to increased disaster vulnerability (Curtis et al. 2007; Zoraster 2010). On the other hand, the link between neighborhood deteriorating conditions and health outcomes post-Katrina has not been established. The first systematic study of impacts of structural features on health was conducted pre-Katrina and thus, long term disaster effects are yet to be related to health (Cohen et al. 2000). In addition, and to the best of my knowledge, no study has investigated whether removal or clean-up of neighborhood and structural level variables may relate negatively to health outcomes in the context of community recovery following disaster events. One study suggested a need for focused interventions on neighborhood deteriorated conditions in order to decrease neighborhood crime and perceptions of neighborhood safety including health outcomes (Curry et al. 2008).

It is important to consider deteriorated neighborhood conditions in studies of neighborhood effect on health because specific neighborhood features have been linked to sexual exposure risk, poor health and physical inactivity (Cohen et al. 2000; Cohen et al. 2006; Hong and Farley 2008). Poor neighborhood conditions can cause significant social, emotional, and physiological problems (Coen and Ross 2006; Matheson et al. 2006; Curry et al. 2008). In addition, living in low income residential neighborhoods can increase residents' susceptibility to vector-borne diseases, often due to poor housing conditions and weak neighborhood infrastructure (Krisberg 2010). The issues of neighborhood conditions have immediate practical implications in the study area. Notably, most severely damaged neighborhoods in the city were areas of concentrated poverty, residence to low income minority populations that if revitalized under pre-Katrina conditions (e.g. with poor-quality resources), a wide range of social disorders, including increased need for mental health will reappear if not persist. As Cutrona and Wallace (2006) argue, "the hopelessness of individual poverty is compounded by community impoverishment".

The present study assesses neighborhood deteriorated conditions as potential risk factors for stress-related mental health and disease transmission. This study expands upon previous research by directly assessing the influence of specific neighborhood structural features on health, which has been understudied. The primary neighborhood disorder (or broken windows) characteristics included within this study are neighborhood structures such as unattended swimming pools, completed property demolitions, imminent health threat and public nuisance property listings. Studies in New Orleans and elsewhere have linked neighborhood disorder to health (Cubbin 2008; Schootman et al. 2010).

1.4 The Use of Geographic Information Systems (GIS) in Health

Assessing the effects of neighborhood-level factors and risks on health has recently been assisted by the use of geospatial techniques such as Geographic Information Systems in conjunction with other data sources (Diez Roux and Mair 2010; Gross and McDermott 2009). Most generally speaking, GIS facilitates the integration of contextual characteristics of neighborhoods or that of individuals to their specific address location(s) in ways that the information can then be geocoded and aggregated to user-defined spatial units such as counties, zip codes, census tracts or block groups (Gross and McDermott 2009). Geospatial tools can also help with statistical problems posed by the lack of independence among observations (spatial autocorrelation) when testing neighborhood effects (Anselin 1988; Anselin and Getis 1992). Its applications to public health and social science are extensive, and the history of its use goes back to John Snow's examination of the cholera epidemic (Cromley and McLafferty 2002). Accordingly, Cromley and McLafferty identify three broad applications of a GIS namely spatial database management, visualization and mapping including spatial analysis. In addition to these functions, GIS can also translate spatial relationships into numerical variables that can be used in statistical analysis (Vann and Garson 2001; Kalipeni and Leo 2010).

GIS has been used in two main ways when assessing neighborhood effects on health outcomes. On a very detailed level, GIS has been coupled with socioeconomic variables to calculate a variety of distance and density measures in order to assess spatial accessibility to services and resources (Kahn et al. 2002; Malczewski and Poetz 2005;Franco et al. 2008). GIS has also been used on a broader contextual level to locate and calculate rates of various neighborhood risks and resources (i.e. crime incidences and alcohol outlets, incivilities, injury hotspots, etc.) (Meersman 2005; Coen and Ross 2006; Brower and Carroll 2007; Schuurman et al. 2009). Combining the detailed examination of the location of the individual with the broader context of the neighborhood has only recently begun to happen (Rushton 2003; Moore and Carpenter 1999; Diez Roux and Mair 2010). Gross and McDermott (2009) use GIS, Census data and city archival data to inform structure measures of neighborhoods for the City of Philadelphia, PA, USA (Gross and McDermott 2009). They found that the combination of city and census dimensions explained significantly more neighborhood effects on school achievement than did either source of neighborhood information independently.

In disaster settings, GIS facilitates emergency planning and response and the rapid assessment of the impact of such disasters (Waring et al. 2005). Two recent studies in New Orleans used GIS and characteristics of neighborhoods such as household income, housing values, poverty and elevation and flood levels to assess the vulnerability to disasters in the context of hurricane Katrina (Curtis 2007; Masozera et al. 2007). They found that pre-existing socio-economic conditions played a significant role in the ability of neighborhood residents' capacity to respond immediately to the disaster and to cope with the aftermath of Katrina. GIS was used to produce action maps used to inform public health policy and resource planning. This project expands on recent work by including fine-grained geographic variables related to the natural, built and social conditions of neighborhoods along with proximity variables at the individual-level to identify, describe and measure the relationship between neighborhood deterioration and health. The use of spatial statistical approaches including Geographical Information Systems (GIS), Spatial Scan Statistics and metrics is emphasized.

1.5 Conceptual Framework of the Dissertation

As reflected in the dissertation title, the aim of this study is to explore neighborhood health risk differentials and implications of neighborhood conditions on various health outcomes in New Orleans. Specifically, I investigate, assess and distinguish, through a quantitative analysis, spatial variation in characteristics of residential neighborhoods (here considered as the 478 Orleans Parish block groups), and characteristics of individuals and their relationship with health. The core argument presented in this chapter and throughout the study is that stressors in the physical environment and/or local neighborhood may primarily influence health outcomes. Figure 1.1 presents a conceptual framework created by Diez-Roux and Mair, *Neighborhood and Health* (Diez-Roux and Mair 2010: 126).

The framework is linked to this research by illustrating the fact that neighborhoods potentially influence health in a number of direct and indirect ways. For instance, race-based residential segregation can lead to inequalities in resources, which can, in turn reinforce segregation. Similarly, neighborhood physical environments and neighborhood social environments also affect each other, for instance; poor neighborhood conditions can affect a neighborhood's ability to form communal ties which can in turn, affect the neighborhood's ability to advocate for improved services. Finally, behavioral and stress processes operating at the individual level are also related; stress may lead people to engage in unhealthy behaviors such as substance abuse and/or smoking as strategies of stress reduction whereas behaviors such as physical activities can neutralize stress.

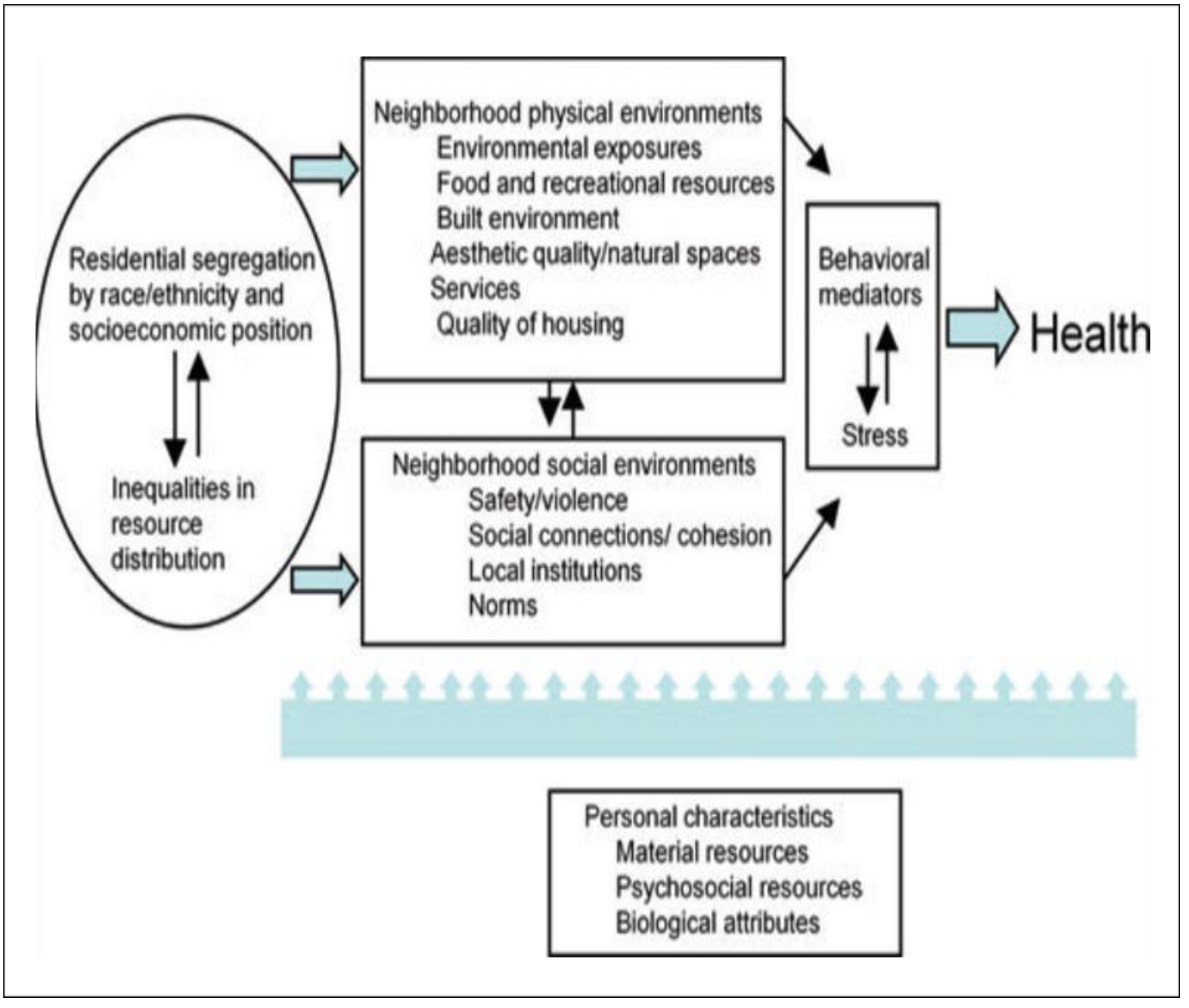

Figure 1.1: Diez and Mair's conceptual framework of mechanisms by which neighborhood environments influences health inequalities.
***Source:* Diez Roux and Mair (2010)**

The approach I take to researching along the above theme is shown in figures 1.2 and 1.3, below. Figure 1.2 illustrates the overall conceptual layout of the dissertation, in all its parts with Figure 1.3 illustrating the organization of the three papers that form this dissertation.

Figure 1.3 (briefly described below) gives a conceptual layout for each of the three papers that link to and build upon one another to form the body of this dissertation. The first paper (Chapter 2) assesses the spatial structure of abandoned and unattended swimming pools over time during post-Katrina years and examines the degree to which this structure description define areas of persistent problems compared to those that improved. I identified spatial variables describing physical and socioeconomic neighborhood characteristics hypothesized to influence the presence or absence of unattended swimming pools in the study area. Based on this, I identified socioeconomic neighborhood characteristics, which form building blocks for independent variables used in the consecutive papers.

In chapter 3 (paper 2) I examine psychological ramifications using pre- and post-disaster hospital admissions data (2004 to 2009) aggregated at block group-level as well as examine the extent to which three disease groupings (stress-related mood and Anxiety, substance abuse and psychosomatic disorders) relate to neighborhood physical environmental conditions. The fourth chapter (paper 3) is more exploratory in nature. Its purpose is to assess *Cx. quinquefasciatus* mosquito abundance and neighborhood correlates that contribute to disease risk.

Taken together, these three chapters contribute to the central theme of this dissertation, as given in Figure 1.2. Chapter 5 synthetizes as well as summarizes the dissertation's major findings of chapters 2 through 4 around that theme, and offers suggestions regarding areas that hold potential for further study.

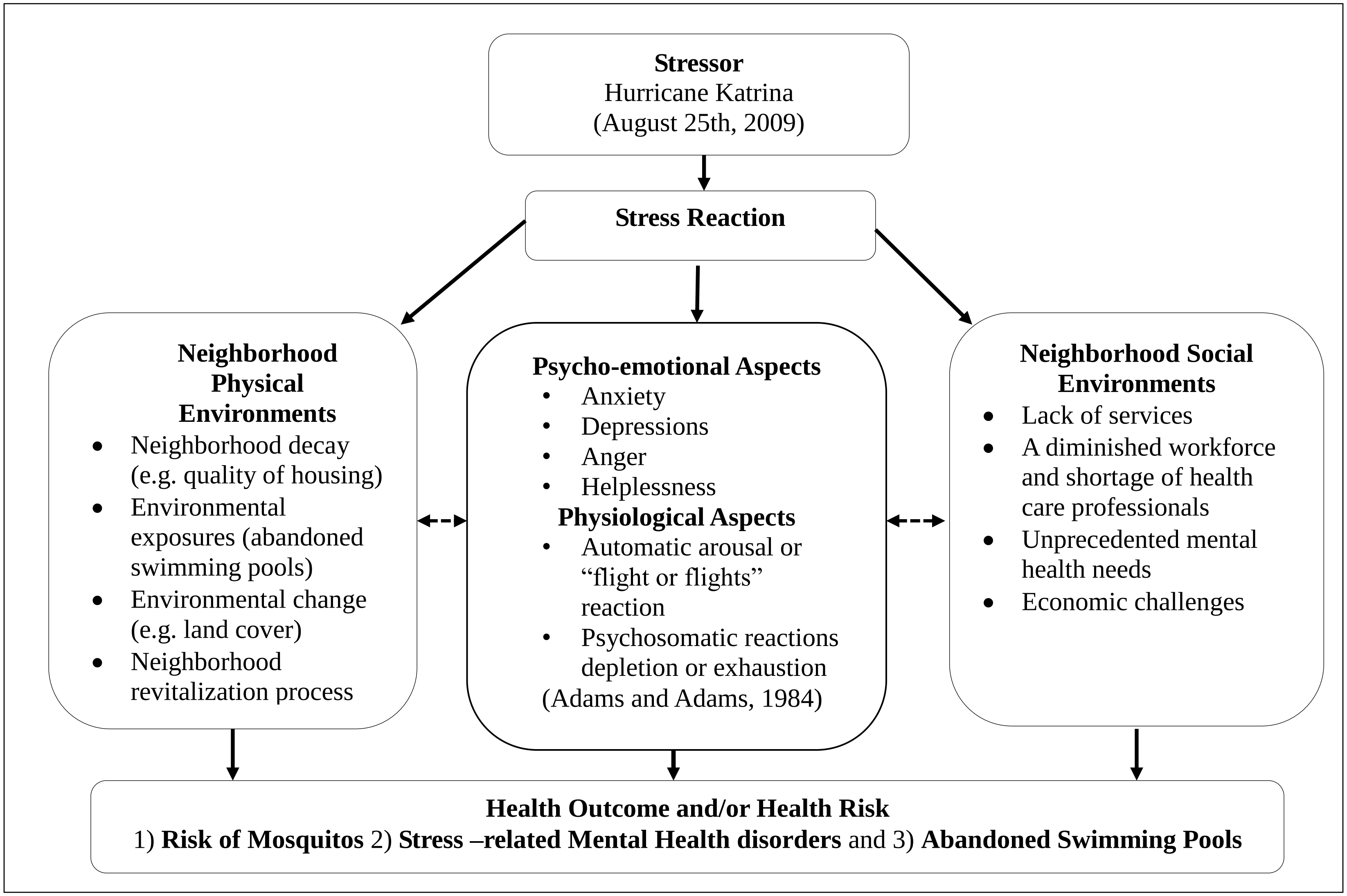

Figure 1.2: Overall Conceptual Diagram

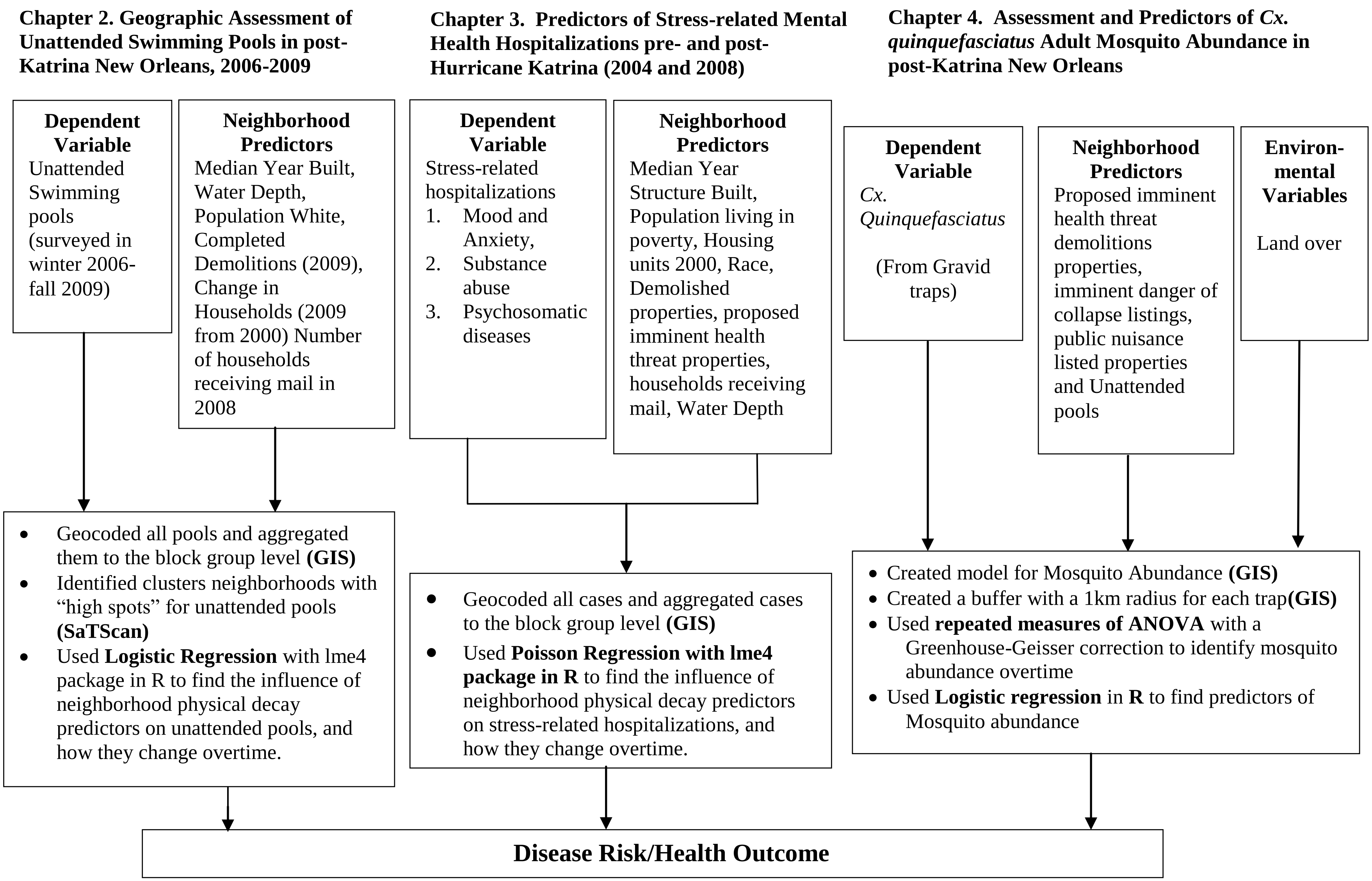

Figure 1.3: Conceptual diagrams for chapters 1, 2 and 3

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CHAPTER 2

GEOGRAPHIC ASSESSMENT OF UNATTENDED SWIMMING POOLS IN POST-KATRINA NEW ORLEANS, 2006-2008

2.1 Introduction

Backyard swimming pools are an important part of expanding suburban landscapes of many cities worldwide, and are especially prevalent in warmer climates. They provide many social benefits such as leisure (Guillam et al. 2010), quality family time (Sanders 2006), and increases in property values (Frederick and Benedict 1981), rehabilitation and improved health (Lehman et al. 2003). In the United States, swimming is ranked third as the most popular sport or exercise activity after exercise walking, working out at clubs, and boating, with roughly 314 million individual visits to both recreational water venues and treated pools each year(U.S Census Bureau 2007). But despite their many benefits, swimming pools have also been associated with negative health outcomes (Shields, Gleim and Beach 2008; Center for Disease Control and Prevention 2011). Evidence indicates that swimming pools are related to infectious disease outbreaks and (Carlson et al. 2004; Lim et al. 2004; Verma et al. 2007; Coetzee et al. 2008; Yoder et al. 2008), to toxic chloramines exposures (Kaydos-Daniels et al. 2008), and to skin and soft-tissue infections (Manresa et al. 2009; Tlougan, Podjasek and Adams 2010).

Recently, researchers have also linked housing foreclosures and disaster events to swimming pool abandonment and vector- borne disease risk. The first systematic study of the effects of foreclosures and abandoned unattended properties with swimming pools and concomitant increases in West Nile Virus was reported by Reisen et al. (2008) (also see Shea

2009 and Goodman and Buehler 2009). In New Orleans, 64 percent of unmaintained sampled swimming pools were found to contain mosquito larvae, primarily *Culiseta inornata* and the arboviral vector *Culex Quinquefasciatus* (Caillouet et al. 2008). Besides neglected pools, other social factors such as, poorer economic conditions, ethnicity and variability in mosquito control have been identified as important risk factors for both vector abundance and West Nile virus in the U.S. (Harrigan et al. 2010; Ruiz et al. 2004; Allan et al. 2008).

Despite, the evidence of their potential importance, no study has investigated the spatial pattern of abandoned swimming pools and their neighborhood determinants in a geographical sense. In addition, studies on neighborhood effects on health have been, up to now, limited to the exploration of geographical variation in resources across socially contrasting residential neighborhoods (Macintyre, Maciver and Sooman 1993; Morland et al. 2002). Recent studies point to how effects within a neighborhood can also affect social processes that operate across a broader geographic context (Coen and Ross 2006; Kramer and Hogue 2009; Diez Roux and Mair 2010; Kramer et al. 2010). Further, to our knowledge, no study has examined deteriorated health promoting infrastructure such as swimming pools in the context of community recovery following a disaster event. Knowledge of the geographical variation in fitness and nutritional-related infrastructure such as fast food restaurants, stores, parks and neighborhood physical activity resources, has significantly increased our understanding of the effects of neighborhood infrastructure on healthy eating (Moore et al. 2009), healthy food shopping behavior (Sparks, Bania and Leete 2010; Grigsby-Toussaint et al. 2010) and physical activity outcomes (McGinn et al. 2007).

In terms of the effects of place of residency on health, studies have found associations between deteriorated neighborhood physical conditions and health (Cohen et al. 2000; Caughy, O'Campo and Patterson 2001; Nsuami et al. 2009). It is suggested that residents of socially and economically deprived neighborhoods are more likely to be exposed to environmental hazards and/or toxics and deleterious neighborhood conditions (Macintyre, Maciver and Sooman 1993; Morland et al. 2002; Harrigan et al. 2010). In addition, several studies have shown that specific features of the immediate physical neighborhood environment may be protective or harmful for the health of residents. For example, Cohen et al. (2000) found a neighborhood index measuring housing quality, abandoned cars, graffiti and public school deterioration to be far more important in explaining the variance in gonorrhea rates than a poverty index. Elsewhere, Coen et al. (2006) found that parks located in socially and economically disadvantaged neighborhoods had more hazards, incivilities[1], fewer exercise facilities, and poorer health outcomes than those in affluent neighborhoods. In other words, specific neighborhood characteristics may pose economic and health threats to both individuals and communities, and increased risk of disease exposure are higher in disaster stricken areas (Nsuami et al. 2009).

Neighborhood characteristics can affect residents' health either directly or indirectly through neighborhood risk factors that accentuate the effect of exposure to risk. For example, unattended pools in New Orleans present direct public health challenges because they provide ideal breeding habitats for mosquito vectors of West Nile virus, eastern equine encephalitis, and St. Louis encephalitis (Marten et al. 2010). On the other hand, although the distribution of unattended pools is not like a communicable disease that diffuses over space through social contacts, their effects can spill over to affect neighboring communities. Pointedly, through abandoned and unmaintained pools, "a deteriorated structural condition" may accrue not just to residents of a particular neighborhood but to those in proximate and adjacent neighborhoods,

[1] Physical incivilities are tangible facets of the neighborhood environment, including graffiti, litter, evidence of vandalism, as well as vacant buildings and lots, and deteriorated properties (Taylor et al., 1985; Perkins et al., 1992).

thus producing spatial externalities (Sampson, Morenoff and Earls 1999). Likewise, blighted neighborhoods (including those with abandoned pools) have been associated with decreased quality of life, decreased property values, constrained community revitalization (Schilling 2004), and have been reported to influence behaviors related to neighborhood flight (e.g. decisions to leave or return to an area) (Inagami, Cohen and Finch 2007; Crowder and South 2008; Billiot, Gilbard and Irving 2010). Thus, identification of the context in which unattended pools are most persistent and concentrated will provide support to efforts to mitigate both the direct and indirect health threats and community problems associated with them.

2.2 Theoretical Framework

This research is based on the Broken Windows theory, which associates the physical decay (decline) of neighborhoods with social conditions such as fear of crime, decision to move and health problems (Wilson and Kelling 1982; Kelling and Coles 1998). The Broken Windows theory suggests that minor public incivilities such as trash, abandoned cars, graffiti, vacant and abandoned and/or neglected properties including unmaintained swimming pools, if ignored, can lead to larger neighborhood problems. Given this, blighted properties need to be deterred or abated to prevent further neighborhood deterioration or decline that can lead to negative economic, social, and physical health.

This investigation uses fine grained geographical administrative data collected for operational purposes among local city departments and geospatial approaches to examine how changing neighborhood conditions after hurricane Katrina affected the probability of the presence of unattended pools. According to Diez Roux and Mair (2010), geographical information systems (GIS) and spatial analysis can be applied to the study of neighborhood effects on health with good effect, and yet until recently both have been frequently ignored by health researchers. GIS, in particular, if used as an analytic tool, offers powerful tools that can be used to investigate spatial relationships in health outcomes (Cromley and McLafferty 2002; Kalipeni and Zulu 2010) and in improving decision-making practices (Wang 2010). In addition to exploring neighborhood predictors associated with unattended pool variability, the present research advances the literature by incorporating a spatial scan statistic to address the temporal and spatial dimensions of neighborhood characteristics on presence of unattended pools in New Orleans. I consider this to be an exploratory study, in which I am primarily interested in identifying areas with a high density of unattended pools. A variety of neighborhood characteristics, including completed demolitions and number of households that received mail post Katrina, as well as socio-economic characteristics such as household income are considered.

Informed by the Broken Windows theoretical framework, the purpose of this chapter is to assess the influence of neighborhood structural deterioration on density of unattended pools among New Orleans block groups and to identify hot spots for unattended pools. Here, neighborhood structural deterioration is treated as properties of block groups within which unattended pools are situated. This study attempted to answer the following core research questions: 1) what is the spatial structure of unattended pools over time during post-Katrina New Orleans? 2) What neighborhood predictors are associated with this variability? 3) How do demographic characteristics and neighborhood structural deterioration affect the odds of a pool being unattended in 2006 immediately after Katrina compared to the longer period from 2006 to 2008 when recovery dynamics may reflect more than the physical effects of the hurricane. Based on the Broken Windows theory, it is hypothesized that neighborhood structural deterioration will contribute to clustering of block groups with persistent unattended pool problems. It's further hypothesized that the presence of unattended pools will vary spatially and temporally. The chapter has four parts; first, it reviews the extant literature relevant to abandoned and unattended pools and neighborhood effects and health. Secondly, the research methodology is presented and data analysis methods are discussed. The article concludes with a discussion of theoretical and policy implications.

2.3 Materials and Methods

Study Setting

The study area includes all of New Orleans, Louisiana, with the 478 block groups used as geographic units (Figure 2.1). Census block groups have been used successfully in similar previous studies including Burton and Price-Spratlen (1999), Goodman and Buehler (2009) and Gross and McDermott (2009). Hurricane Katrina struck New Orleans on August 29th 2005 and since then, the city of New Orleans has been faced with a challenge of abating unattended pools that were abandoned and/or unmaintained for months to years after the disaster forced residents to move and resettle elsewhere (Gabe et al. 2005; Martin 2007). The plethora of blighted[2] properties and neglected (un-chlorinated) pools placed a large amount of responsibility and work on city staff that were working with limited time and resources to inspect and issue code violations citation (McGinn et al. 2007). In fact, by the end of April 2008, the City of New Orleans had more unoccupied houses than any city in the country, with an estimated 40,000 blighted properties (City of New Orleans Department of Code Enforcement 2008). According to a recent policy research shop brief by the Loyola University of New Orleans, blight has become a determining factor in measuring neighborhood recovery rates. Fortunately, there have been no major outbreaks in vector-borne diseases in the city. The lack of disease cases can partly be

[2] Blight is an official legal designation for properties that are vacant, uninhabitable, and hazardous. Some of these properties also have swimming pools.

explained by the strong mosquito control program implemented by the City of New Orleans Mosquito and Termite Control Board immediately following the disaster in treating abandoned swimming pools (Marten et al. 2010).

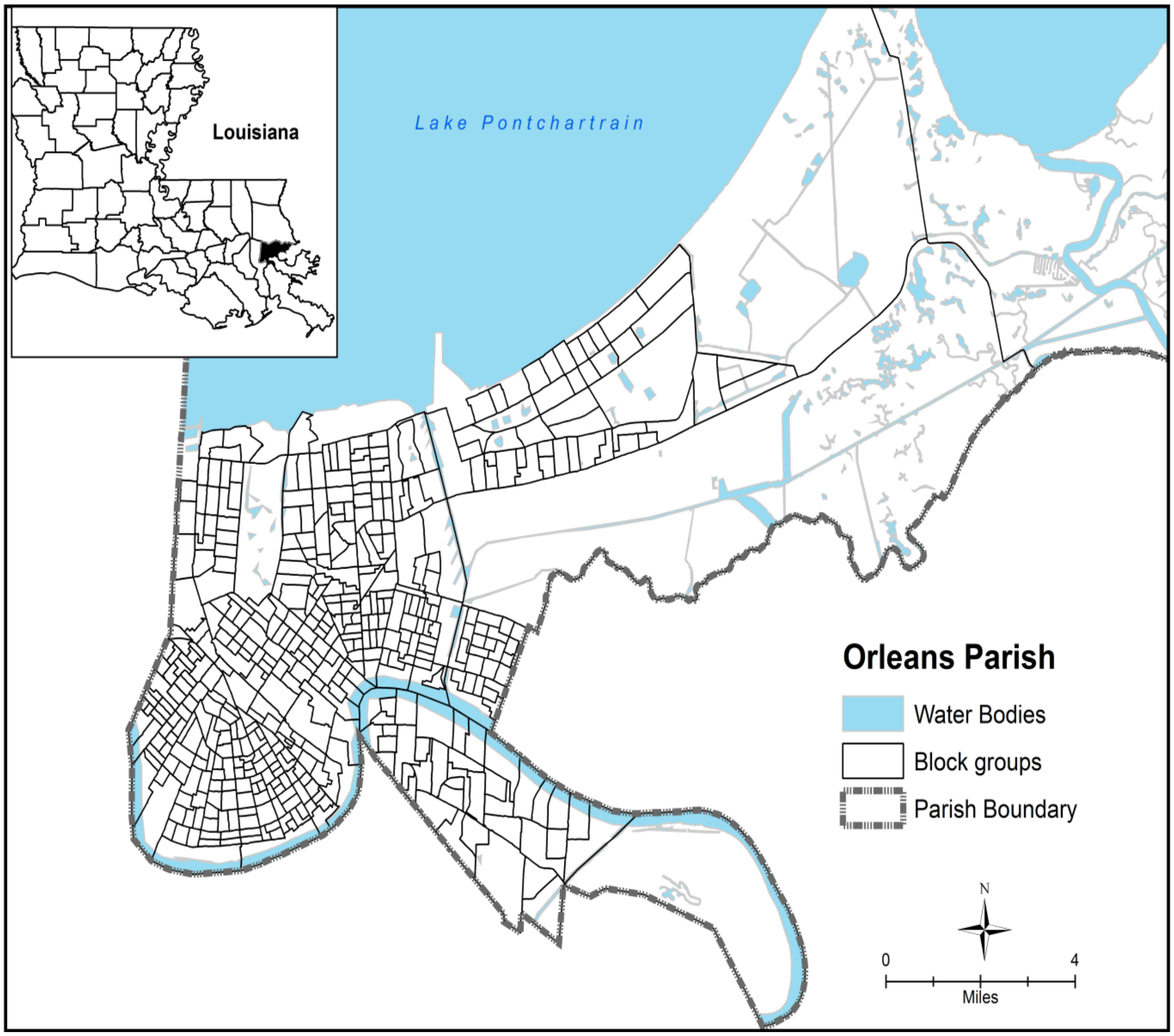


Figure 2.1: New Orleans and its 478 block groups used in the study

2.4 Data Sources

Pool data

Data on the status of 7,170 pools were acquired from the City of New Orleans Mosquito and Termite Control Board (NOMTCB). The data were collected from fall 2006 to spring 2009 through a combination of techniques. Identification of pools was first based on city pool permits. Then, since not every pool had a permit on record, field inspections were implemented. Organization of the data on pools was hampered by missing addresses that were either washed out during the storm or were not visible due to overgrown grass and dilapidated properties. In January 2007, the city acquired Pictometry images (Pictometry International Corp 2008, Rochester, New York) from the New Orleans Police 911 Service to aid in locating known pools and to identify additional new pools that were otherwise unrecorded.

During inspections, field inspectors used a standard survey form to describe each property. Collected data included pool type and status, with indications of whether a pool was operational, removed, filled, unattended, drained, or covered with pool conditions relative to mosquito breeding potential noted. A pool was considered unattended if it was un-chlorinated, unmaintained, abandoned and provided ideal breeding habitat for mosquito vectors (Marten 2010). In some cases, mosquito larvae were collected, with accessibility of pool and any homeowner response towards property accessibility for inspection noted. A total of 18,253 pool inspections were carried out during the study period. All data were geo-coded and aggregated initially to the 478 New Orleans block groups using ArcGIS version 9.3.

Neighborhood Variables

Socio-economic data at the block group were obtained from the U.S Census Bureau American Community Survey 5-year estimates (2005-2009) (US Bureau of the Census 2012). Definitions for the socio-economic variables and descriptive statistics used in this study are provided in Table 2.1. Data on the number of households receiving mail from June 2005 through June 2009 (measure of neighborhood recovery) were obtained from the Greater New Orleans Community

Data Center which originally purchased the dataset from Valassiss Lists (Lists 2009). These data were already aggregated to the block group level.

To capture hurricane Katrina flood impact, a flood depth grid for Jefferson, St. Bernard and Orleans Parishes was downloaded at http://www.katrina.lsu.edu**.** The mean water depth (variable impact) for each block group was derived using the Spatial Analyst tools feature.

Table 2.1: Descriptive statistics of selected neighborhood built environment, disaster impact, neighborhood recovery and socio-demographic risk factors associated used by block group (N=478)

Characteristic	**Min.**	**Max.**	**Mean**	**SD**
Median year house built	0.0	2005	1940	154.86
Median Household Income	0.0	$249,375	$39,591	$29,423
Population density	0.0	12,018	2,603	1,933
Water depth during the flood (impact)	0.0	8.68	2.714	2.25
Households receiving mail (June 2005)	0.0	1,911	414	246
Households receiving mail (June 2008)	0.0	1,803	300	216
Households receiving mail (June 2009)	0.0	1,744	317	222
Public nuisance properties (2010)	0.0	17	1.03	2.17
Completed property demolitions (2006-2009)	0.0	111	5.65	14.05
Imminent health threat properties (2009)	0.0	33	2.16	3.56
Vacant properties	0.0	394	82	66
Change in households 2000 to 2005 and 2009	0.0	1,392	233	170
Population Hispanic	0.0	504	29	58
Population White	0.0	2,654	195	279
Population Black	0.0	3,868	421	469
Population on public assistance	0.0	1,349	227	164
Population living below poverty level	0.0	1,392	234	170

Finally, neighborhood physical decay variables were chosen based upon the Broken Windows theory (Wilson and Kelling 1982; Cohen et al. 2000; Kruger 2008), as described in the introduction section of this paper. These data were gathered from the City of New Orleans department of Code Enforcement via http://www.nola.gov/ and they included a list of completed demolitions, proposed imminent health threat demolitions and danger of collapse, and public nuisance properties. Data on pools, demolitions, and imminent health threat listed properties were aggregated to New Orleans' 478 block groups using the geocoding functionality within ArcGIS software package.

2.5 Methods

Cluster detection

The Kulldorff Scan Statistics Version 9.1 (Kulldorff 1997) was used to detect clusters of unattended pools and to identify their approximate location. The software can be downloaded at http://www.satscan.org. In this study, both the space-time permutation (a cylindrical window search) and the purely spatial Poisson model (a circular window search) were used to detect clusters of unattended pools among New Orleans block groups during the study period. The purely spatial Poisson models were run in addition to the space time analyses to test for spatial patterns. The analysis was performed using the count of unattended pools data for the years 2006 to 2008 aggregated at the block group level. If necessary, assessed variables used in the spatial scan statistic were transformed to satisfy assumptions of normality and heteroscedasticity.

The space-time analyses were performed first with the parameter for the space-time set to a maximum cluster size and temporal scan window of 50 percent of the total population at risk in order to scan for small to large clusters that are localized in both space and time. Thus, the larger maximum cluster size allowed by the software was used because "smaller maximum cluster sizes result in a larger number of smaller clusters with more extreme values" (Green et al. 2003, pg. 553). Unattended pools (cases), ACS five-year population estimates (2005-2009) and a coordinates data file were used as inputs in SaTScan. Data were aggregated yearly. A study period of 1 January, 2006 to 31 December, 2008 was used. Scanning was set to search only for clusters with high numbers of unattended pools. To ensure sufficient statistical power, the number of Monte Carlo replications was set to 999 iterations, and clusters with statistical significance of $p<0.05$ were reported. Also, no geographic overlap was used as a default setting so secondary clusters would not overlap the most significant cluster.

The parameters for the purely Poisson method were set using the same parameters as used in the space time analyses while ignoring time. Only statistically significant results are reported for both the space time and the purely Poisson method. Clusters were not adjusted for temporal trend because the purpose was in identifying areas within New Orleans with high unattended pools. Neighborhood level factors were then aggregated to the cluster areas with analysis of variance performed in order to identify their possible relationship to presence of unattended pools in block groups.

Statistical Analyses

Multilevel logistic regression with random effects in R package lme4 (Linear mixed effects) (Bates and Maechler 2009), version 0.999375-35 was used to investigate whether the likelihood of an unattended pool presence was related to the selected neighborhood predictors described below for year 2006 and for all three years combined (2006, 2007 and 2008). A binary logistic regression approach was adopted over a spatial autoregressive method based on the Charlton and Fotheringham (2009)'s recommendation to use the spatial autoregressive method when the dependent variable is 0/1. Moreover, since the raw proportion of unattended pools for many block groups was less than 10 percent, the Poisson model is not appropriate, either. Notably, the Poisson model assumes an infinitely large population from which counts are drawn. In most cases, the population will be finite (a fixed number). Counts from finite populations follow the Binomial distribution, not the Poisson distribution. However, if the size of the population is large relative to the number of counts, the Poisson distribution can be used as an approximation to the Binomial distribution. But in the case of swimming pools in the current study, the population of pools is not very big. More importantly, the number of unattended pools is rather large, relative to the total number of pools.

Furthermore, for each pool on record, the dependent variable (0, 1) indicated whether the pool was unattended or attended. A normally distributed random effect was added for each block group to account for correlations between pools due to un-modeled variation between block groups and since the response variable is presence or absence (0/1) of unattended swimming pools out of a fixed number for each block group, normal linear regression is not appropriate either.

Variables used in the analysis were chosen by adding them one at a time to the regression model and retaining only those that were significant predictors. Of the 17 variables (Table 1), 6 were retained in the analysis: median year house built, water depth, percent white, percent change in households (2005-2009 over 2000), percent households receiving mail by June 2008 and percent completed demolitions (2006-2009). None of the variables under investigation demonstrated inter-correlations >0.50, which indicated that there was no multicollinearity (Table 2.2). In addition, dummy codes were used for year in the multi-year swimming pool analysis. The specific logistic regression model fitted to the data was as follows:

- Model for 2006:

$$\log \frac{\pi_{ij}}{1-\pi_{ij}} \beta_o + \beta_1 Depth_j + \beta_2 \%\, White_j + \beta_3 \%\, Change\ in\ Households_j$$

$$+ \beta_4 \%\, Completed\ Demolitions_j + \beta_5 Median\ Year\ Built_j + U_j$$

- Model for all three years (2006, 2007 and 2008)

$$\log\frac{\pi_{ij}}{1-\pi_{ij}}\beta_o+\beta_{0t}Time_t+\beta_{1t}Depth_jTime_t+\beta_2\%\ White_j+\beta_3\%\ Change\ in\ Households_j$$
$$+\beta_4\%\ Completed\ Demolitions_j+\beta_5 Households\ Receiving\ Mail\ in\ 2008_j$$
$$+U_j$$

Where π_{ij} is the probability of pool i in block group j being unattended out of all pools in block group, and U_j are independent, normally distributed random effects for block groups.

Table 2.2: Correlation matrix of the neighborhood predictors for all the variables used in the analysis

	Median Built	Water Depth	Households Mail	Completed Demolitions	Population White	Change in Households
[a]Median Year Built	1					
[b]Water Depth	0.046	1				
[c]Receiving Mail	0.012	-0.497	1			
[d]Demolitions	0.033	0.321	-0.321	1		
[e]Population White	0.043	0.043	-0.233	-0.227	1	
[f]Change Households	0.126	0.126	0.199	-0.252	0.229	1

[a]Median year structure built (2005-2009), US Census Bureau; [b]Water Depth as measured by the flood depth map obtained on August 29th 2005; [c]Percent households receiving mail by June 2008 as captured by the US Postal Service; [d]Percent completed demolitions between 2006 through 2009; [e]Population white, US Census Bureau 5-year (2005-2009) estimates, American Community Survey; [f]Percent change in households between the 2000 Census and the 5-year ACS estimates (2005-2009).

2.6 Results

In New Orleans, 2,092 of 7,170 pools were unattended in 2006. These swimming pools were abandoned, non-chlorinated or poorly maintained and had potential for becoming breeding grounds for mosquitoes, as well as drowning hazards. Of these, 1,191 (17%) were unattended in 2007 and 438(12%) in 2008, resulting in an overall unattended pool presence rate of 8.2, 4.35 and 1.30 pools /1000 population, respectively. Importantly, unattended pool density was higher among block groups that exhibited high levels of flood depth during hurricane Katrina (Figure 2 and 2.3A-C).

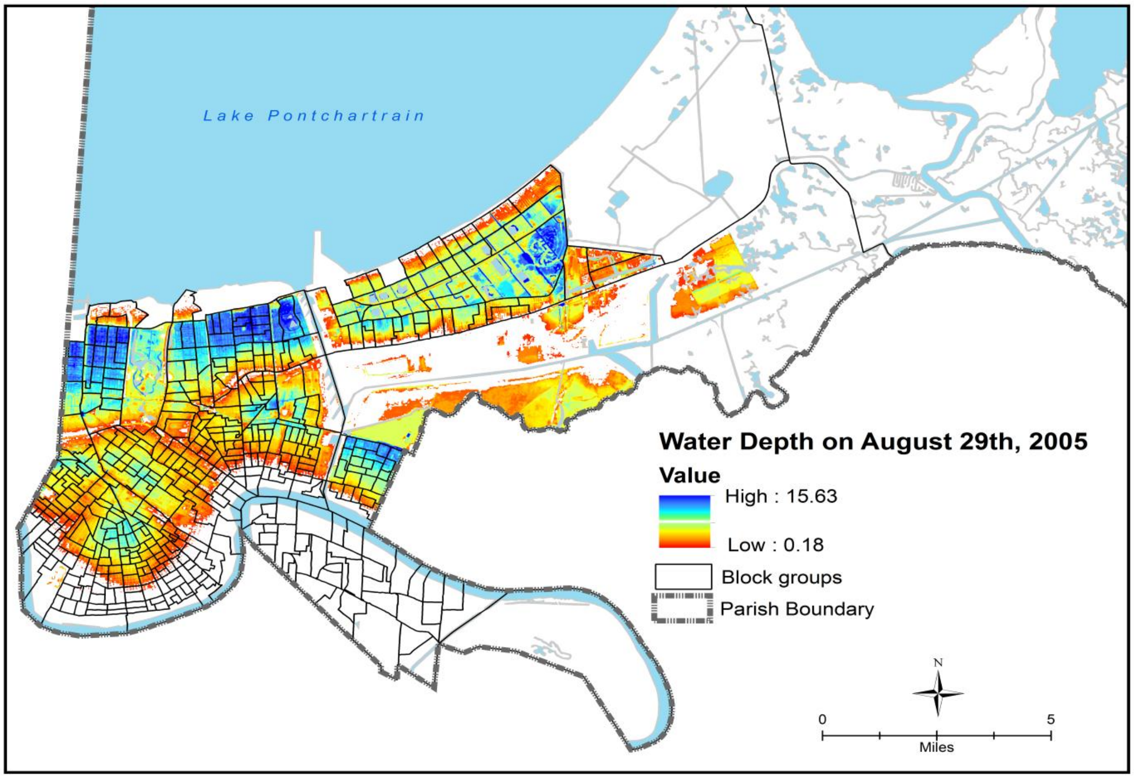
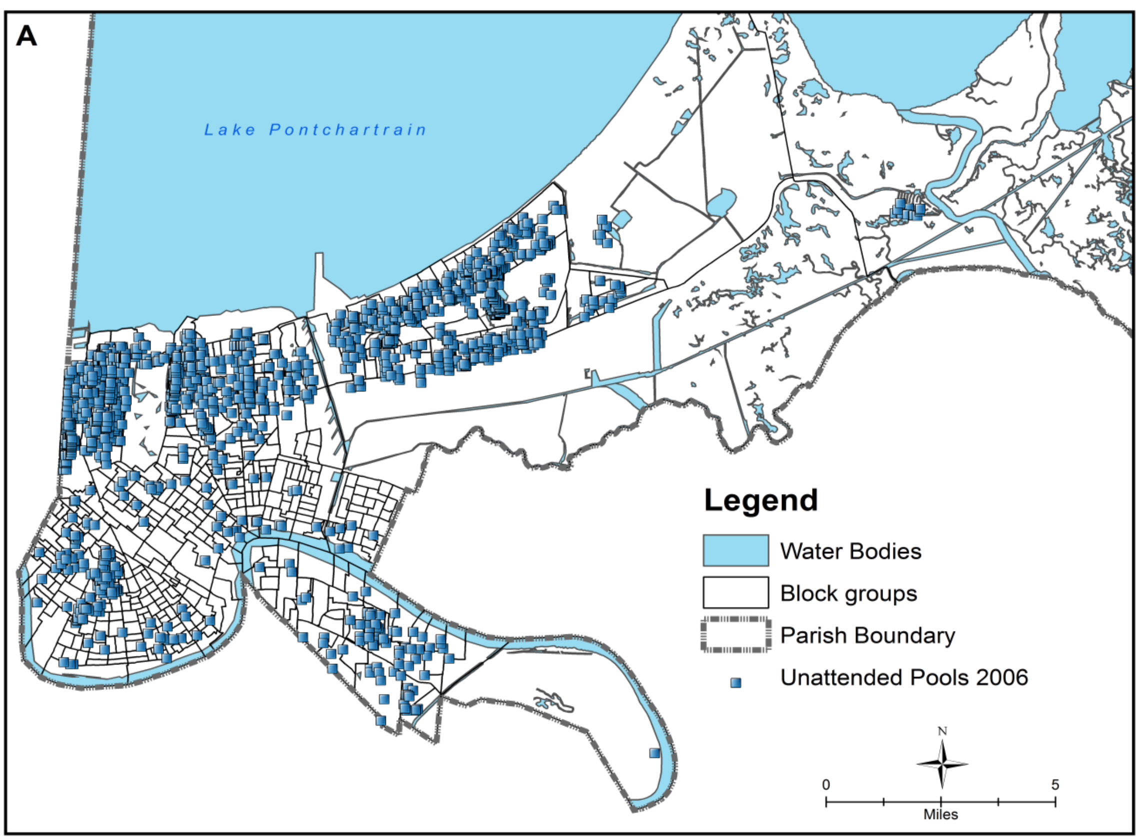
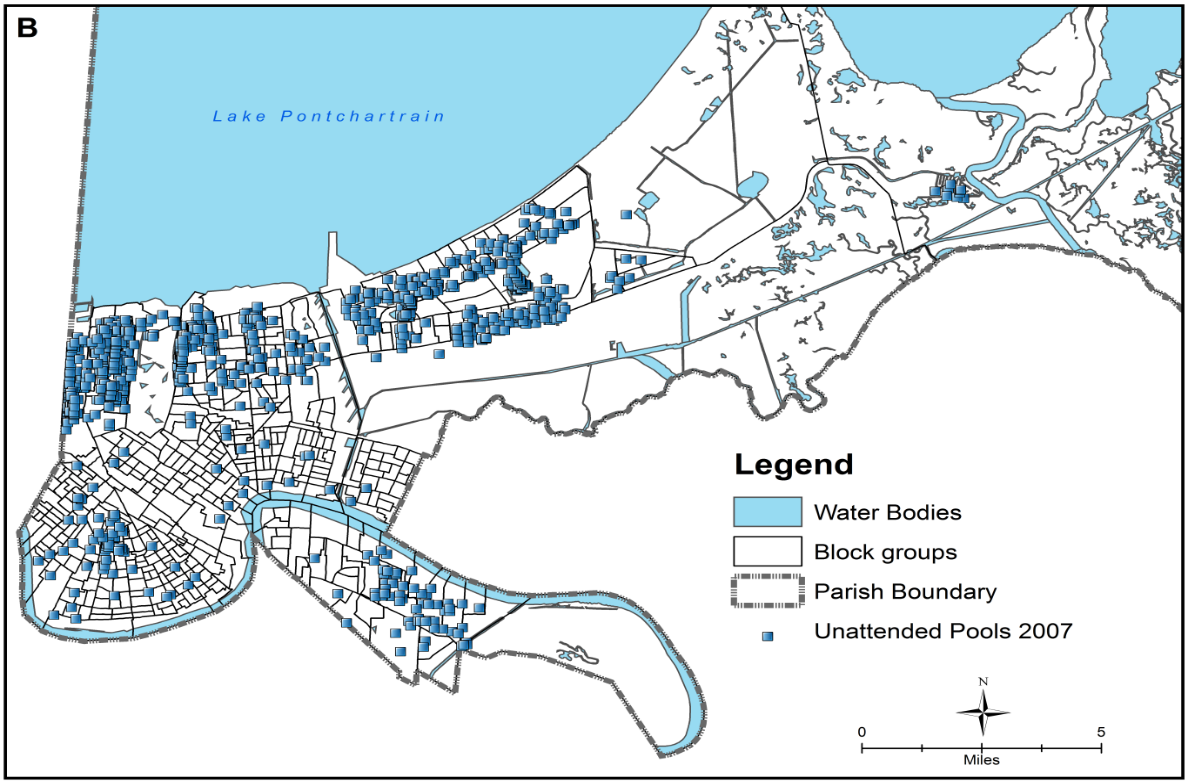


Figure 2.2: Flood Water Height, August 29th, 2005





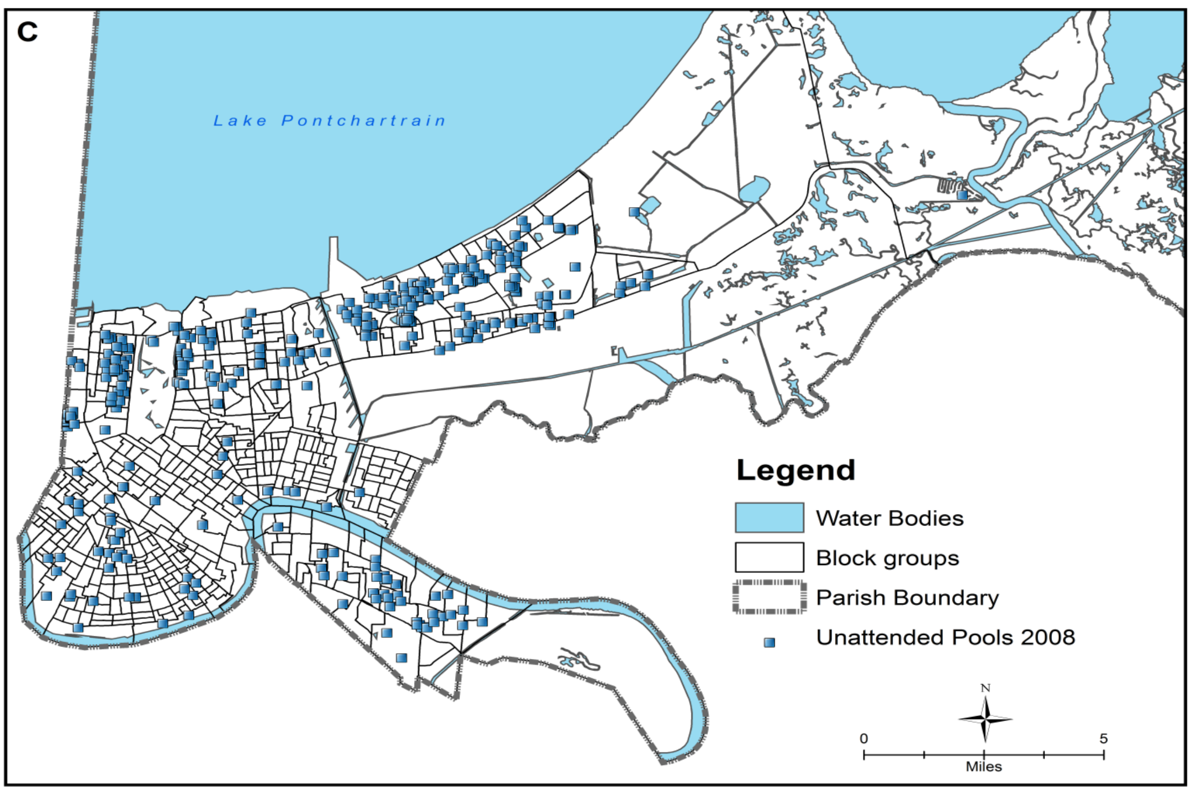


Figure 2.3A-C: Unattended Pool Density, New Orleans, 2006, 2007 and 2008

Spatial Scan Results

Table 2.3 shows the results applying the spatial scan statistics. With the maximum cluster size set at 50 percent of the total study population, two significant (*P*<0.000) clusters were detected for both the purely spatial model and space time model. The high relative cluster from the purely spatial model is the most likely cluster and has relative risk (RR) = 11.61 and log likelihood ratio (LLR) = 1,396.58, with the first secondary cluster RR = 4.49 and LLR = 734.12. Figure 2.4Ashows that the high RR cluster from the purely spatial model is located in the north around the Lakeview and Gentilly neighborhoods, while the first secondary cluster, from the same model is located in New Orleans East (an area located in the east of the Industrial Canal and north of the Intracoastal Waterway). Two other smaller secondary clusters with RR = 6.02 and 8.06, and a LLR = 15.71 and 31.60 were located in the core around Mid-City and the Algiers neighborhoods.

Table 2.3: Unattended Pool analysis, City of New Orleans, 2006 to 2008, using the spatial scan statistic

Max. Cluster size		Purely Spatial	Space Time
Most likely primary cluster			
50%	Cases	1,023	940
	Expected	125.92	62.92
	Relative Risk	11.61	20.97
	Log Likelihood Ratio	1,396.58	1,805.01
	P-value	<0.000	<0.000
Secondary Cluster 1			
50%	Cases	1168	1,008
	Expected	346.45	173.11
	Relative Risk	4.79	8.13
	Log Likelihood Ratio	734.12	1,072.67
	P-value	<0.000	<0.000

Relative risk = Observed unattended pools/expected unattended pools

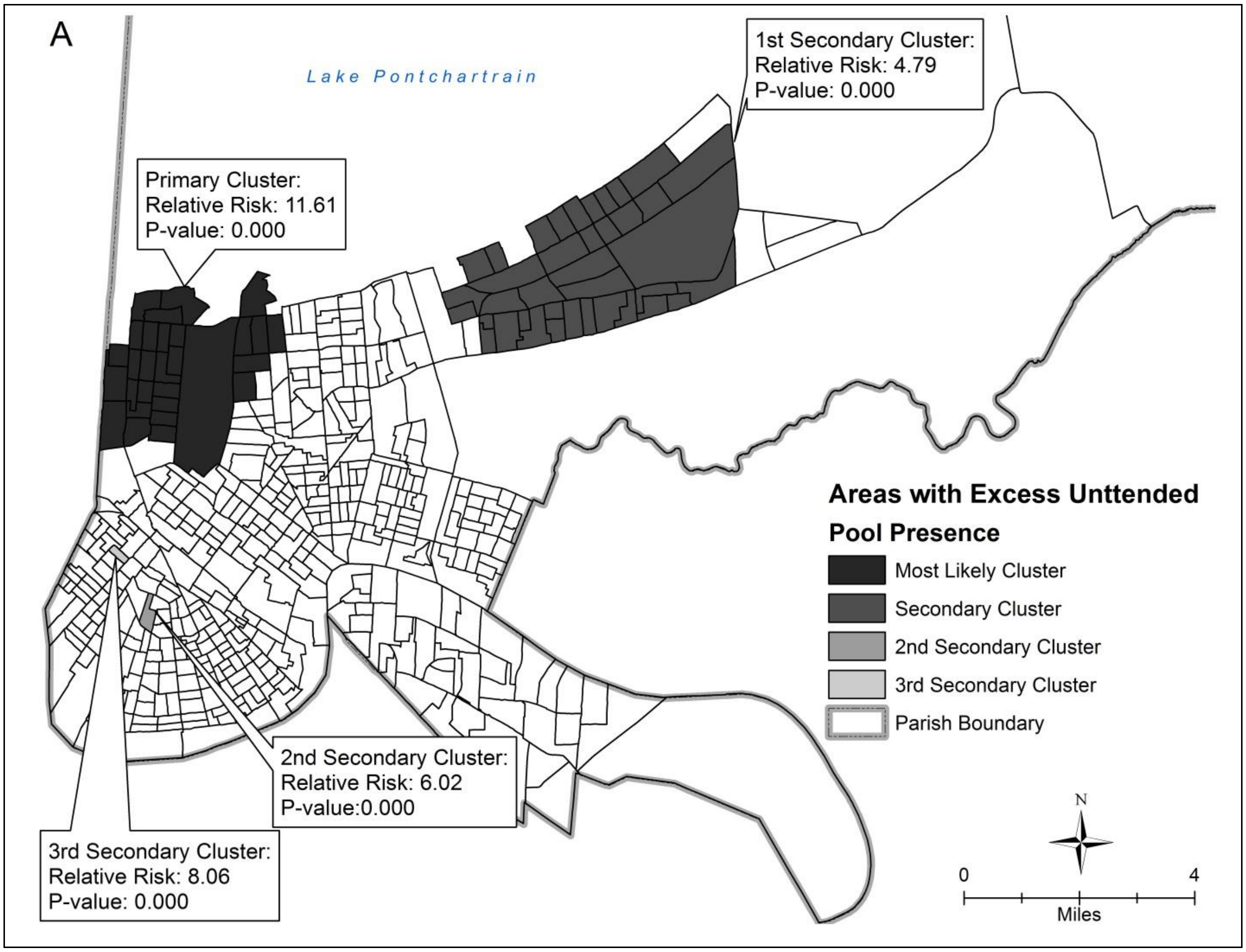


Figure 2.4A: Unattended pool Analysis, New Orleans, 2006-2008, using the Purely Spatial model

The space time model detected five significant clusters (*P*<0.000). Relative risk ranged from 2.98 to 20.97. Figure 2.4B shows that the high RR clusters are again all located in the northern part of the city, and among block groups that are located in New Orleans East. The most likely primary cluster, with RR = 20.97, and LLR=1,072.67 is located in the Lakeview and Gentilly neighborhoods. Two additional clusters were also observed located in the core of the city with RR = 4.50, and LLR= 48.94, RR= 2.98 and LLR=18.23. Another smaller secondary cluster was located in the Algiers neighborhood with RR= 8.31, and LLR=14.83. The most likely cluster for the space time model occurred during January 1, 2006 to December 31, 2007, the time in which the number of pool inspections had increased, and pool surveillance program enhanced. Notably, by 2006, the department of New Orleans' Mosquito and Termite Control Board (NOMTCB) had enlisted numerous volunteers to help inspect homes with pools and had acquired Pictometry images from the New Orleans Police 911 Service. Inspection pool efforts and surveillance were expedited as the NOMTCB was able to locate known pools and/or identify additional new pools that were neither located with city permits records or field inspections (Marten et al. 2010).

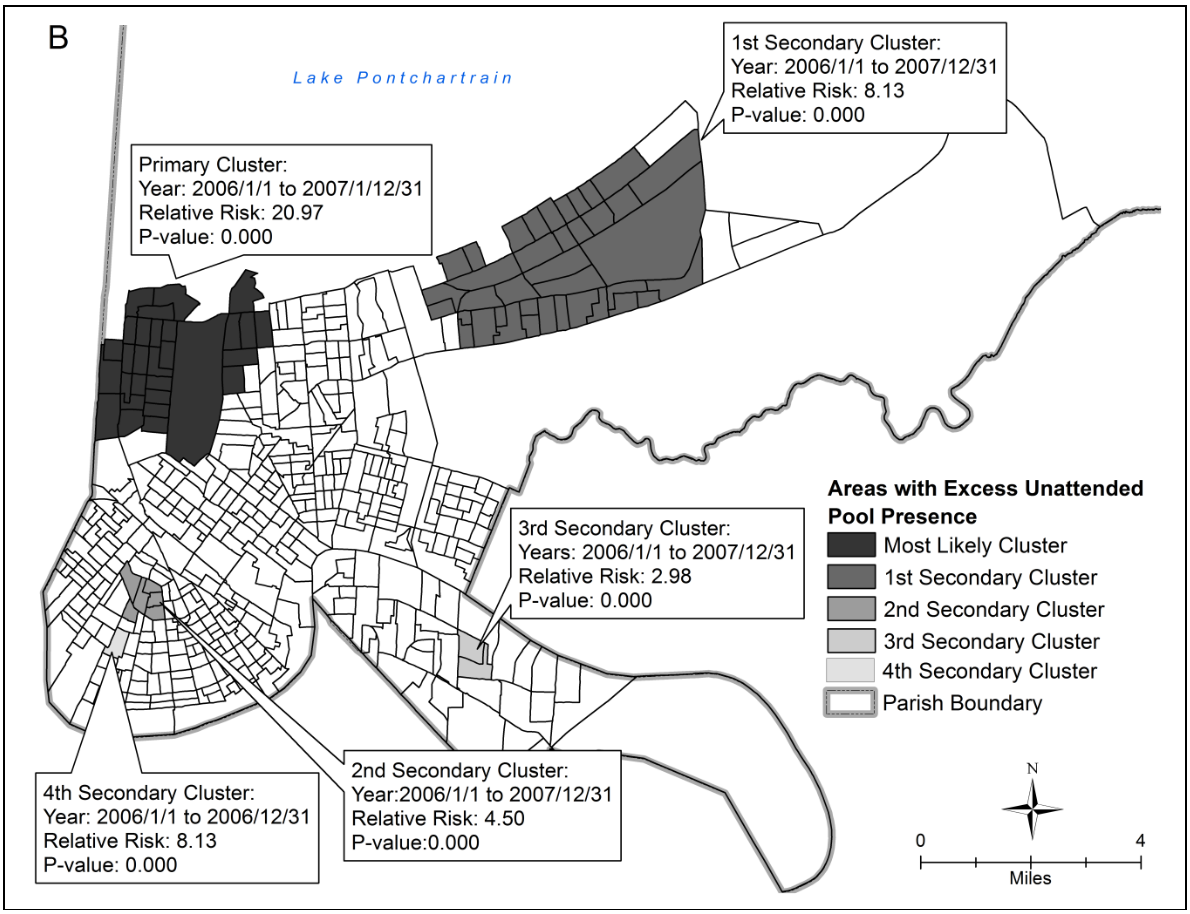


Figure 2.4B: Space Time model from Spatial Scan Statistic, Maximum Cluster size set at 50% of Study Population

Table 2.4shows the predictor variables aggregated to the cluster areas detected by both the purely spatial and space time model from the spatial scan statistics. From this table we can see that a high density of unattended pools detected by the most likely cluster is clustering in those block groups of New Orleans which received greater flood depth, have a high white population and high median household income. In addition, unattended pools were common among block groups that exhibited high population density and a high number of houses built during the 1960s. On the one hand, a high count of unattended pools detected from the first secondary cluster is observed among low income and non-white neighborhoods with homes built during the 1970s. From this table, it's apparent that fifty-two percent of households receiving mail by June 2008 are located among block groups generated in primary and secondary clusters. Analysis of variance was undertaken for all predicator variables, and in all cases, the between cluster variance was significant at the *p*<0.005 level.

Table 2.4: Analysis of variance, predicator variables aggregated to the cluster areas for unattended pool presence detected by the purely spatial and space time models from the spatial scan statistic, maximum cluster size set to 50%

Predictor[a]	**Most likely Cluster**		**1st Secondary Cluster**	
	[b]Purely Spatial	[c]Space Time	Purely Spatial	Space Time
Median Year House Built	1961	1961	1971	1971*
Median Household Income	$80,211	$80,211	8,410	$38,410*
Population Density/square mile	1,048	1,048	1,610	1,610**
Water Depth	6.02	6.02	3.87	3.88*
Percent Households receiving Mail	52.47	52.47	*52.72	52.72**
Percent Population White	60.28	60.29	4.24	4.24*

*P<0.000; **P<0.05.
[a]Water Depth as measured by the flood depth map obtained on August 29th 2005; Percent households receiving mail by June 2005 as captured by the US Postal Service; [b]Purely Spatial model-most likely cluster with relative risk >11(log likelihood ratio =1,396.59,1st secondary cluster with relative risk > 4.79(log Likelihood ratio= 734.12); [c]Space Time model-most likely cluster with relative risk >20.97(log likelihood ratio =1,805.01,1st secondary cluster with relative risk > 8.13(log Likelihood ratio= 1,072). Relative risk-observed unattended pools/expected unattended pool occurrence.

Logistic Regression Results

Table 2.5shows the results of the logistic regression with random effects predicting the likelihood of unattended pools in 2006. A strong relationship exists between proximity to the disaster as measured by greater flood depth and older homes with more unattended pools (P<0.000). The odds of an unattended pool occurrence increases by 33 percent for each additional foot of flooding. There were fewer unattended pools in those neighborhoods that were predominantly white, had more completed demolitions and exhibited a positive change in number of households. After controlling for these explanatory variables, no other neighborhood variables were significant predictors of unattended pools in 2006.

Table 2.5: Logistic regression predicting the likelihood of unattended pool presence in City of New Orleans in 2006

Predictor	Estimate	Std. Error	Z-value	Pr (>|z|)	Odds Ratio	95% CI
(Intercept)	-54.0648	8.582949	-6.299	0.000 ***	3.3109	0.00-0.00
Median Year House Built	0.02654	0.004375	6.069	0.000 ***	1.0268	1.02-1.04
Flood depth	0.28158	0.004375	9.444	0.000 ***	1.3252	1.31-1.34
% WHITE	-0.0087	0.001840	-4.753	0.000 ***	0.9913	0.99-0.99
[a]% Change in Households	-0.0129	0.003163	-4.082	0.000 ***	0.9871	0.98-0.99
[b]% Completed Demolition	-0.1653	0.058420	-2.829	0.005 **	0.8476	0.76-0.95

***P< 0.001 ** P< 0.01, Generalized linear mixed model fit by the Laplace approximation. [a]Percent change in households between the 2000 Census and the 5-year American Community Survey Estimates (2005-2009). [b]Number of completed demolitions between 2006 through 2009. CI- Confidence Interval

Table 2.6 shows the model results of all three time periods combined (2006, 2007 and 2008). The odds ratio (OR) of a pool being unattended was 0.46 (P<0.000) in 2007 and 0.29 in 2008 (P<0.000). Further and compared to 2006, the presence of unattended pools decreased by 54 percent in 2007 and 71 percent in 2008 in the study area. As is expected, the level of flooding has a weaker association with the odds of a pool being unattended as time goes on as evidenced by the interaction terms between flood depth and time. Also, the rate of a pool being unattended decreased for each foot of flooding over time (In 2006 OR = 0.29, 95% CI= 1.20-1.38; in 2007 OR=0.22, 95% CI= 0.90-1.00 and in 2008 OR=0.03, 95% CI= 0.75-0.86). Neighborhoods that had a high proportion of white population, households that received mail by June 2008 and completed demolitions had fewer unattended pools (OR=0.98, 95% confidence interval (CI) =0.99-0.99; OR= 0.98, 95% CI=0.98-0.99; and OR =0.82, 95% CI= 0.74-0.90, respectively). Median year house built was necessarily dropped from the regression, as it caused convergence problems. Otherwise, the effect of the other explanatory variables does not change over time.

Table 2.6: Logistic regression predicting the likelihood of occurrence of unattended pools in the City of New Orleans over the three time period (2006, 2007 and 2008)

Predictor	**Estimate**	**Std. Error**	**Z-value**	**Pr (>|z|)**	**Odds Ratio**	**95% CI**
(Intercept)	-0.566700	0.404068	-1.402	0.160	0.5673	0.26-1.25
Time 2(2007)	-0.773155	0.120563	-6.413	0.000***	0.4615	0.63 -0.58
Time 3(2008)	-1.228967	0.146374	-8.396	0.000***	0.2925	0.22-0.39
% WHITE	-0.011669	0.001658	-7.038	0.000 ***	0.9884	0.99-0.99
% Household Receiving	-0.014177	0.003903	-3.633	0.000 ***	0.9859	0.98-0.99
[b]% Completed Demolition	-0.204244	0.052402	-3.898	0.000 ***	0.8153	0.74-0.90
Time 2(2007); Flood depth	-0.054209	0.026817	-2.021	0.043 *	0.9472	0.90-1.00
Time 3(2008): Flood depth	-0.217688	0.033691	-6.461	0.000 ***	0.8044	0.75-0.86
[c]% Change in Households	-0.003947	0.003018	-1.308	0.190	0.9961	0.99-1.00
[d]Flood depth	0.251243	0.035220	7.134	0.000 ***	1.2856	1.20-1.38
Flood depth*Time 2 (2007)	-0.054209	0.026817	-2.021	0.043 *	0.9472	7.55-1.04
Flood depth*Time 3 (2008)	-0.217688	0.033691	-6.461	0.000 ***	0.8044	0.00-1.00

Significance codes: *** P< 0.001 ** P< 0.01 * P< 0.05
Generalized linear mixed model fit by the Laplace approximation. [a]Households receiving mail by June 2008, [b]Number of completed demolitions between 2006 through 2009. [c]Percent change in households between the 2000 Census and the 5-year American Community Survey estimates (2005-2009). [d]Water height as measured by the flood depth map obtained on August 29th 2005. CI-Confidence Interval

2.7 Discussion

The present study was designed to determine the effect of neighborhood deterioration on odds of a pool being unattended in post Katrina New Orleans. A variety of physical neighborhood deterioration risk factors were considered for which previous research has shown strong empirical or theoretical support. Surprisingly, the results of this study suggest that variables associated with neighborhood deterioration (e.g. vacant houses, properties with major structural damages including broken windows), do not provide as robust an explanation for presence of abandoned and unattended swimming pools in New Orleans. This suggests that it may be more of the effect of neighborhood demographics and underlying preexisting characteristics of neighborhood conditions influencing unattended pool presence rather than the physical deterioration of neighborhoods to which unmaintained pools contribute.

A high density of unattended pools in a block group could be interpreted as simply a marker of preexisting structural and demographic factors that were exacerbated by hurricane Katrina's devastating impact on August 29th, 2005. This also suggests that interventions targeted at decreasing the density of unattended pools including blighted properties in New Orleans, will require an integrated and area specific approach which examines whether it is a neighborhood's unique set of circumstances (e.g. social and physical circumstances) that contributes to the presence of unattended pools and their persistence. Also, the most likely clusters of unattended pools appeared almost two years post-hurricane Katrina, a time by which the department of New Orleans' Mosquito and Termite Control Board had acquired Pictonometry images that in turn enhanced pool inspections and surveillance.

Perhaps the most interesting findings are related to the interaction of time with flood depth in estimating the likelihood of a pool being unattended over time. When considering associations of neighborhood deterioration with unattended pool presence, it is perhaps surprising that the number of completed demolitions and percent change in households are significant variables while most other neighborhood variables are not. In addition, their effect is intuitive –completed demolitions, number of households receiving mail by June 2008 and a positive change in number of households (2000 from 2005-2009) in a block group is associated with a decrease in the likelihood of a pool being unattended or abandoned. Evidently, the number of completed demolitions in a block group is not a sign of neighborhood decay but a sign of recovery, or perhaps greater access to insurance that facilitates demolitions and neighborhood revitalization. It is also possible that the number of households receiving mail by June 2008 variable captures the presence of returning home owners maintaining their own pools.

A similar though perhaps less surprising result with regards to associations of race, proximity of a neighborhood to a disaster and a high density of unattended pools is found, where flood depth is positively associated with a higher density of unattended pools and the population being white has a negative association. These results are consistent with those of other studies and suggest that disaster impacts are experienced differently by those living in close proximity to a disaster event and by different racial and ethnic groups (Bolin 1986; Fothergill, Maestas and Darlington 1999; Curtis, Mills and Leitner 2007). In fact, an earlier post-flood survey in Charlotte, South Carolina, showed that black respondents were more likely to estimate higher property damages due to flooding than white respondents (Ives and Furuseth 1983).

In this study, it was also observed that the block groups with the highest unattended pool density also had distinct socioeconomic status and high population density. For example, the mostly likely cluster which also happens to have the highest relative risk for unattended pools in the city is located among block groups that are characterized by a median household income that is one of New Orleans's highest. To contrast, the first secondary cluster block groups are located in New Orleans East -an overwhelmingly African-American low income community by 2005 (Bennett et al. 2011). This observation suggests that the spatial pattern of unattended pools in New Orleans is, to some degree, a function of economic disparity.

An unanticipated finding was the link between older homes and a high density of unattended pools. This result is similar to that generated by the analysis of variance exploring predictor variables aggregated to clusters of unattended pool. The analysis demonstrated that the highest density of unattended pools were clustered in block groups that have a high number of homes that were built during the 1960s and are mostly located in the Gentilly and Lakeview neighborhoods and those located in New Orleans East and built during the1970s. A possible explanation for this might be due to the fact that apartment complexes built in the 1960s and 1970s in New Orleans, in particular, those located in New Orleans East, are predominantly inhabited by upwardly-mobile young singles, mostly African American and are often female headed households (Bennett et al. 2011). This finding is in agreement with Cooper and Laughy's (1994) findings which showed that the occupants of older apartment buildings in the United States are predominantly minorities and ethnic groups, and that these apartments are among those most susceptible to damage in disaster events due to unreinforced masonry (Bolton, Liebow and Olson 1993).

This study raises questions about how we need to better understand and mitigate specific neighborhood level factors that could either inhibit or promote health outcomes of residents. This study has documented that block groups in the northern and eastern parts of New Orleans are associated with a high density of unattended pools. These northern and eastern area block groups are places whose persistent presence of unattended pools seemed to have emerged as a result of their geographical proximity to the disaster and underlying structural characteristics of exposed neighborhood elements that made them susceptible to damage. This has likely occurred as a result of social, geographical and economic forces. The result has been the transformation of the immediate neighborhood physical environment of these areas into places of risk with the presence of unattended pools having strong association with neighborhood recovery variables and race.

A major strength of this study was its use of data from the Census Bureau and locally accessible city administration data that are collected as a normal requirement in running New Orleans city departments. This accords with Gross and McDermott (2009)'s earlier observations, which showed that city administration data are collected on a more continuous basis than Census data and thus their scope is more reflective of the socio-dynamic and economic processes that distinguish one block group from another. Thus, any relationships that may be detected between the spatial units and unattended pools in current study are likely to be detected in spite of, not due to, issues of data quality.

2.8 Study Limitations

The study was limited in several ways. The first limitation is attributed to the study design as this study began in 2007, almost 2 years after the disaster. Thus, the pre- and immediate effects of the hurricane on unattended pools in study area cannot be assessed. The evaluation of pre-Katrina pool characteristics and conditions (e.g. how many pools had water and/or were filled or unattended) would have offered validity to pre-post hurricane effect comparisons. However, given the current study's post-hurricane effect focus on unattended pools, the observed correlations are likely real and significant.

Secondly, although the spatial scan statistics have many advantages, they are prone to exhibit "edge effects" (Kulldorff and Hjalmars 1999), which can result in biased estimates of unattended pool risk on the periphery of study block groups. As much of the unattended pool data is found along the edges of block groups (i.e., a pool could be located near the boundary of its host block group, or at the border between two block groups), this issue remains a concern. These results therefore need to be interpreted only under the assumption that the number of unattended pools (cases) to population at risk in the area of the circle encompassing one host block group is similar or close to that in the neighboring or adjacent block group. However, since the purpose of the study was to assess the influence of neighborhood structural deterioration on density of unattended pools and to identify hot spots for unattended pools, the likelihood of finding significant *hot* spots by chance alone was increased. Likewise, although no adjustment for edge effects was made; the study methodology legitimately provides important clues to the geographical distribution of unattended pools among New Orleans block groups. It suggests that the presence of unattended pools in the study area is negatively influenced by proximity to the disaster, neighborhood structural condition and presence of neighborhood residents (as measured by number of households receiving mail).

Third, the study makes no distinction between the different types of unattended pool characteristics or condition and how that might have changed overtime, all important components to exposure and risk. Given that unattended pool characteristics may change based on returning homeowners maintaining their own pools coupled with the NOMTCB's targeted efforts in treating unattended pools in the study area, caution must be taken in concluding that all unattended pools in study area pose identical health risk.

Finally, there are also limitations implicit in using logistic regression. Mainly, logistic regression assumes that observations are independent, given the fixed and random effects. In this case, it was assumed that the random effects for block groups are independent. It is also assumed that the random effects for block groups are normally distributed. However, if there are spatial correlations, the independence of block groups assumption is violated. Moreover, in the three-year model, since the same pools are observed at three time points, the independence of observation assumption is also violated, since if a particular pool is unattended in one year, it may be more likely to be unattended in another year as well.

Despite these limitations, the findings from this study have important implications for other cities, counties and states and their local city departments as they address issues of abandoned swimming pools of foreclosed homes. Importantly, it should be noted that the effect of neighborhood demographics and underlying preexisting characteristics of neighborhood conditions seem to be influencing unattended pool presence in the study area rather than the physical deterioration of neighborhoods of which unmaintained pools contributes. Therefore, in order to more fully understand how the problems of unattended pools has happened over time, the intrinsic neighborhood characteristics of how these high-risk block groups have evolved over time have to be explored more carefully through the use of diverse vulnerability methods that allow for exploration of why unattended pools exist or persist.

This suggests that prevention and intervention efforts that focus on one single overarching cause of foreclosed homes with unattended pools will likely not be successful. There is a need to address latent causal factors if immediate health risks caused by foreclosed homes with unattended swimming pools are to be corrected and prevent other problems from emerging. This combination of findings provides some support for the conceptual premise that "risk assessment, reduction and transfer are the major elements of risk management" (Dilley et al. 2006, pg. 21). Most importantly, perhaps, mitigation of foreclosed homes with abandoned pools should be implemented with the realization that the ability of cities to effectively carry out surveillance and mitigation of these neighborhood facets will vary widely from city to city, and may change within a city based on the internal capabilities of the local government and neighborhood residents' spirit of volunteerism.

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CHAPTER 3

RISK FACTORS FOR MENTAL HEALTH DISORDERS HOSPITALIZATION, NEW ORLEANS, PRE- AND POST-KATRINA

3.1 Introduction

Five years after hurricane Katrina devastated the city of New Orleans on August 29th 2005, mental disorders have increasingly become recognized as an issue that has impacted the city's health care and infrastructure revitalization process (Calderon-Abbo 2008; Madrid et al. 2008; Bentham et al. 2011; Olteanu et al. 2011a; Wennerstrom et al. 2011). Growing evidence suggests that hurricane Katrina had both short and long-term psychological effects on community residents (Rhodeset al. 2010). In one rapid-needs assessment conducted in October 2005 by the Centers for Disease Control and Prevention, 50% of survey respondents reported a need for immediate mental health assistance and 33% had ongoing needs for mental health services (Rhodes et al.2006). A survey conducted between January and March 2006 found half (49.1%) of pre-Katrina New Orleans residents to have a 30-day prevalence of DSM-IV[3] anxiety-mood disorders compared with 26.4% of the other residents in the sample (Galeaet al. 2007).The survey also yielded high rates of reports of post-traumatic stress disorder (PTSD) (30.3%) among New Orleans residents compared to 12.5% among those living in Alabama, Louisiana, and Mississippi. In a cross-sectional survey of 222 New Orleans Katrina survivors, 52% reported they continued to experience poor mental and physical health 15 months after Katrina (Kim et al.

[3]Psychiatric Diagnoses are categorized by the Diagnostic and Statistical Manual of Mental Disorders, 4th. Edition.

2008). The researchers also found that pre- and post-Katrina depression and being female were significant predictors of poor mental health.

Other studies in New Orleans have noted even longer adverse mental health effects on the general population (Ginzburg 2008; Kessler et al. 2008; Wang et al. 2008; Schoenbaumet al. 2009; Rhodes et al. 2010). Stress-related symptoms and medically unexplained physical symptoms have been higher in women, mothers of young children, low income and racial minorities, and among those who work with severely traumatized patients and residents (West et al. 2008; Blodorn and O'Brien 2011; Culver et al. 2011; Tees et al. 2010). While categorized somewhat differently, other studies have associated hurricane Katrina with increased substance use (e.g. (Cepeda et al. 2010b; Rowe et al. 2010; Tharpet et al. 2011).

Although prior research has made significant contributions to our understanding of the association between impacts of hurricane Katrina and mental health in New Orleans, much of the research up to now has been qualitative in nature (e.g. based on interviews), or has relied on small community samples and has been performed on selected populations, such as mothers of infants, police or health care professionals. Few studies have systematically examined mental health outcomes using inpatient and outpatient data (Xiong et al. 2010; Olteanu et al. 2011b) or used these data to examine mental health outcomes across a more diverse pre- and post-Katrina New Orleans population. In addition, associations between hurricane-related stressors and mental health have been made, but little is known about the relationship between socio-demographic and neighborhood decay variables and rates of stress-related disorders in these neighborhoods (Galea et al. 2007). Olteaau et al. (2011) used clinical data from a comprehensive healthcare program to look at the mental health needs of children four years post-Katrina. Their study demonstrates an effective use of hospital admissions data. Galea and colleagues (2007) found no association between socio-demographic variables and mental disorders in the city but that ongoing hurricane-related stressors in New Orleans are widespread. The researchers conclude by asserting that practical problems associated with ongoing hurricane-related stressors must be addressed if the prevalence of mental disorders is to be reduced in the city of New Orleans (Galea et al. 2007).

The purpose of this study was to (1) assess rates for mental health stress-related disorders in the city of New Orleans for three time points (2004, 2008 and 2009), (2) identify neighborhood and socio-demographic risk factors associated with stress-related mental disorders in New Orleans for the three time points and, (3) examine the extent to which the odds of acquiring a mental stress-related disorder increases or decreases over time (between 2004, 2008 and 2009). It was hypothesized that poor neighborhood and socio-demographic conditions increase stress-related mental disorders in the study area.

The chapter has four parts. First, it provides a brief literature review on impacts of hurricane Katrina on mental health and highlights the relevant disaster literature that has been conducted in the study area. Secondly, the context of New Orleans and the state of the medical infrastructure across the community is presented to provide a contextual framework for the analysis. This is followed by a description of data and data sources and methodology used. The chapter concludes with a discussion on protective and risk factors for stress-related mental disorders arising as a result of the hurricane Katrina.

3.2 Materials and Methods

Study Design

This was an observational study of the Louisiana inpatient hospital discharge data among persons 0-100 years of age in New Orleans between 2004, 2008 and 2009. To identify stress-related mental disorder admissions, cases with admission ICD-9 (International Classification of Diseases) diagnosis codes associated with specific mental health disorders (ranging from 390 to 459) were selected. To map a particular disease, the single level clinical classification System (SLCCS) (AHRQ, online) was used to group the different the ICD-9- codes into three disease groupings namely; mood and anxiety, stress-related psychosomatic and substance abuse disorders (Table 3.1). The study method of disease disorder selection is based on previous research that links major disasters to emotional distress, substance abuse and consequent mental illness (Galea et al. 2007; Yun et al. 2010). The substance abuse disease grouping includes all alcohol-related and substance-related mental disorders. Mood and anxiety includes affective, anxiety and personality disorders, other mental conditions, shock and mental and behavioral problems observations. Also included are disorders known to have stress related origins (psychosomatic) and have an effect on mental functioning. A list of these disorders was compiled using Greenberg's *Comprehensive Stress Management*, Eighth Edition book (Greenberg 2008). Psychosomatic disorders are those disorders in which the state of mind (psyche) either causes or mediates a condition of actual, measurable damage in the body (soma) such as rheumatoid arthritis or peptic ulcers (Despues 1999).

The primary source document for the requested data is Uniform Billing (UB)-04 claim forms (AHIMA Clinical Terminology and Classification Practice Council 2007). UB-04 claim forms are used to bill for all inpatient, outpatient and emergency room services across the United States. Due to the use of identifiable information (e.g. patient residential addresses), the Louisiana Department of Health and Hospitals' (LDHH)'s ethical review Board in Baton Rouge, Louisiana and the Institutional Review Board of the University of Illinois at Urbana-Champaign reviewed and approved this study, which was conducted in accordance with the (Health Insurance Portability and Accountability Act of 1996) HIPAA privacy rule.

Table 3.1: Disease Groupings of Stress-related Disorders used in analysis

Disease Grouping	Disorders
*Stress-Related Psychosomatic Disorders (n= 3,314)	Allergic reactions, Asthma, coronary atherosclerosis and other heart disease, headache including migraine, hypertension (essential), rheumatoid arthritis and related disease, stroke
Mood and Anxiety Disorders (n= 1,937)	Affective disorders, anxiety somatoform dissociative and personality disorders, other mental conditions, personal history of mental disorders and behavioral problems observations, mood disorders, shock
Substance Abuse Disorders (n=2,219)	Alcohol-related mental disorders, substance-related mental disorders

*Stress-Related Psychosomatic Disorders were compiled based on Greenberg's Comprehensive Stress Management, Eighth Edition book, Greenberg 2008.

Health Care Infrastructure Pre- and Post-Katrina

New Orleans' health infrastructure and inpatient mental health services have changed since Katrina. Health professional shortages, an increase in the number of traumatized residents and challenging work environments have presented difficulties for those working in health care and undermined the quality of health and mental services in the city (Meyers et al. 2011). Consequently, this has shifted mental health treatment to primary care physicians with emergency departments functioning at full capacity (Foley 2007; Calderon-Abbo 2008; McKenna and Kaiser 2008; PharmacoEconomics 2008).

Notably, pre-Katrina, New Orleans was served by a "two-tier" mental health system. Residents with private insurance or Medicare relied heavily on private and community hospitals, while the uninsured relied almost exclusively on state hospitals such as the then Medical Center of Louisiana at New Orleans-Charity Hospital and clinics affiliated with the state's Office of

Mental Health, Louisiana State University, and Tulane (Calderon-Abbo 2008). In 2004, the city had 196 psychiatrists, 254 functioning adult psychiatric beds and 22 operating hospitals, including 9 acute care hospitals (Calderon-Abbo 2008). These provided both inpatient and outpatient services for a population of 443,430 with an average hospital occupancy rate of 56 percent, about 3.03 hospital beds per 1000 population (Berggren and Curiel 2006; Demographia 2006; Radowitz et al. 2006). Of the 254 functioning adult psychiatric beds, 114 were in privately operated hospitals, 140 in public hospitals and 25 at the Veterans Affairs Medical Center (Gautam et al. 2009) and the remaining 115 were at Charity Hospital (Calderon-Abbo 2008).

Post-Katrina, the city has been subjected to a complex set of health care services and associated infrastructure problems, particularly in relation to mental health services. In 2006, with Charity Hospital closed and without the VA Medical Center, the psychiatric bed capacity in the city was reduced by 70 % to about 17 mental health beds, and only 22 psychiatrists for a population of 327,228 (Louisiana Healthcare Redesign Collaborative 2006; Griffies 2010). In all, only 9 hospitals were operational (US Politics, Undated). Accordingly, on April 24th, 2006, the U.S. Health Resources and Services Administration designated New Orleans “a health professional shortage area” with one psychiatrist for every 21,000 people and one primary care doctor for every 3,000 residents (New Orleans Recovery Initiatives 2006; Griffies 2010). This was a drastic drop compared to one physician per 333 residents in 2001(Rudowitz et al. 2006).

Nevertheless, although significant positive improvements in health infrastructure have been made, including an increase in organizations offering health services to uninsured patients and an increasing system of neighborhood-based primary care clinics, notable challenges persist. In 2008, three years after the disaster, only 13 hospitals with 2000 beds were operational with 65 psychiatrists in the city for a population of 321,405 (Berggren and Curiel 2006; GRC &

Associates Inc., http://www.gcr1.com/; US Politics, Undated). Similarly, there has been an increased demand for health care services from returning residents in need of mental health services; a high burden of uninsured patients (e.g. low income and unemployed residents who relied on Charity Hospital) and high caseloads.

3.3 Data Sources

Hospitalization data

Hospitalization data cover all admissions reported to the Louisiana Department of Health and Hospitals' (LDHH) Bureau of Policy Research and Health Systems Analysis database based on passive surveillance. That means that passive surveillance will usually only detect disease in those who get sick, suggesting that healthy carriers and long incubation periods combined with passive surveillance can maintain a reservoir of undiscovered mental health cases. For the years analyzed, data includes both public and private hospitals in New Orleans but it excludes military and Veteran Administration hospitals as they are outside the jurisdiction of the LDHH. Abstracted from this database were a patient's address, zip code, city, date of birth, sex, marital status, race, admission date, admissions diagnosis-code and description, principle diagnosis description and code, billing information and Encounter ID. The Encounter ID field allows separate admissions encounters by the same patient to be linked. For example, since a patient may be treated more than once for a disorder, an algorithm was developed using the Encounter ID and other identifiers (e.g., gender, address, and date of birth) so that only the first encounter in each year for a particular disease was used to calculate hospitalization rate. It should also be noted that no information on capacity of each hospital (number of beds) that feed into the LDDH database were available to estimate adjusted annual incidence for each disease- a major study limitation as noted in the discussion section.

All data were geo-coded and aggregated initially to the 478 New Orleans block groups using ArcGIS version 9.3 (Environmental Systems Research Institute (ESRI), Inc., Redlands, California, 1999) (Figure 3.1**.** Excluded data in final analyses included data on patients with a P.O. Box address, missing address information and/or addresses listed as unknown, homeless (including addresses that were out of New Orleans) and those that could not be verified by Google maps due to data entry errors. Overall, 234 of 3,434 total cases were excluded pre-Katrina and 346 of 2,363 in 2008 and 100 of 2,353in 2009 (post-Katrina). The final database comprised 7,470 unique patients encounter IDs (3,200 in 2004, 2,017 in 2008 and 2,253 in 2009). The number of encounters pre-Katrina is much higher than post-Katrina in part due to population differences, and variations in number of hospitals feeding into the system resulting in consequent disparities in the need for mental health care services over time.

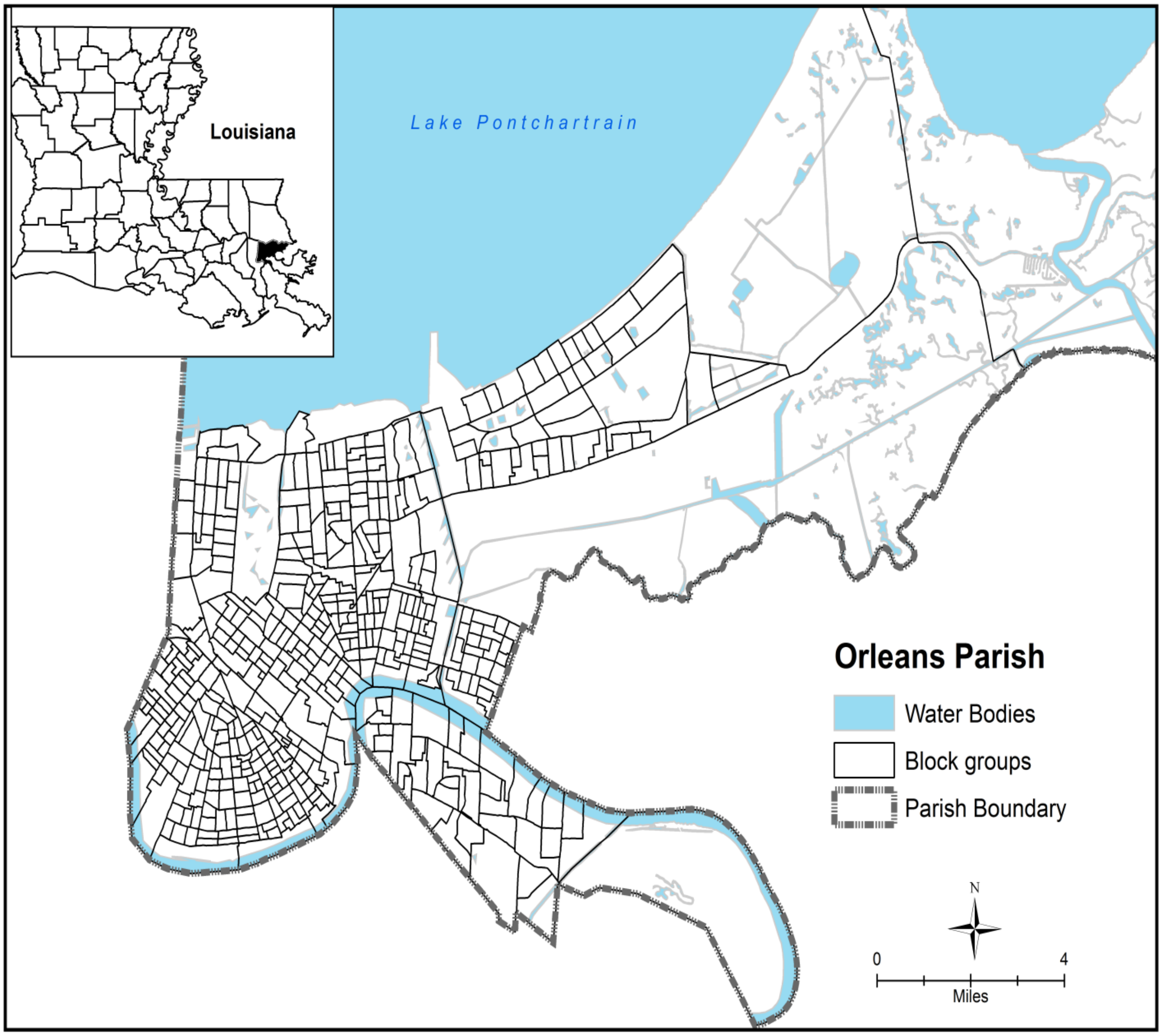

Figure 3.1: Location of Orleans Parish and its 478 block groups that were used in the study

Pre-Katrina Neighborhood Predictors used in analyses

Neighborhood variables measuring the physical conditions of New Orleans neighborhoods were obtained from various city departments and from the US Census Bureau. To analyze the pre-Katrina rates of mental health disorder hospitalizations, neighborhood-level (block group) socio-demographic predictors from the US Census Bureau Census 2000 were used. These variables included total population, race, median age, percent of vacant houses, and percent population in poverty, median household income, and median year structure built, single headed households, owner occupied and renter occupied. The block group was used as the unit of analysis because "although block group boundaries are arbitrary and may have little meaning to residents, block groups are more representative of local neighborhoods than the larger census tracts" (Cohen et al. 2000, pg. 231).

Post-Katrina Neighborhood Predictors used in analyses

To capture the effects of neighborhood physical conditions on mental health hospitalizations in post-Katrina New Orleans, the American Community Survey (ACS) 5-year estimates (2005-2009) were used. Neighborhood-level (block group) socio-demographic predictors included race, percent of vacant houses, and percent population in poverty, median household income and median year structure built. Although census data have been used as a proxy for neighborhood characteristics and in identifying associations between socioeconomic disadvantage and health outcomes with good utility (Laraia et al. 2006), in New Orleans, with over fifty percent population displaced, Census population estimates are unreliable. Instead, population estimates were obtained from GRC and Associates Inc., (GRC & Associates Inc., http://www.gcr1.com/). GRC's population estimates are based on indicators of residential occupancy (termed as "activity index") calibrated against base population data from the 2000 Census and calculated using residential occupancy indicators including active utility accounts, active postal delivery accounts, active Sewage and Water Board accounts, active sanitation accounts, and voter registration and participation. The estimates were from 2006 through 2009 and were at the block group level. No 2004 population estimates were available from GRC Inc.

Sources for neighborhood decay and recovery measures include the city of New Orleans Code Enforcement website (via http://www.nola.gov) and the Greater New Orleans Community

Data Center, which originally purchased the dataset from Valassis Lists (counts based of active residential addresses) (Data Driven by Valassis Lists 2011). Data from Valassis were already aggregated to the block group for the years 2005 to 2010. Measures of neighborhood decay predictors included imminent danger of collapse listings, public nuisance properties[4] (2010) and imminent health threat property listings whereas neighborhood recovery predictors included percentage of households receiving mail by June 2008 and June 2009 and completed demolitions (2006-2009). The percentage of households receiving mail predictor was used to capture residents that stayed through Katrina or returning residents.

Neighborhood physical decay variables were chosen based on the Broken Windows Theory (Wilson and Kelling 1982). The Broken Window Theory associates the physical decay of neighborhoods with disease risk, fear of crime and health problems and can be applied to this study with good effect. In fact, one study in New Orleans demonstrates how a neighborhood decay index measuring housing quality, graffiti, garbage, abandoned cars and public school deterioration explained more of the variance in gonorrhea rates than did a poverty income index measuring income, unemployment, and low education (Cohen et al. 2000). Low-income individuals living in neighborhoods indexed with low levels of decay had significantly lower gonorrhea rates than their counterparts living in neighborhoods characterized by high levels of decay (Cohen et al. 2000).

Lastly, to capture hurricane Katrina's flood impact across New Orleans neighborhoods, a water depth grid was acquired (downloaded at http://www.katrina.lsu.edu). Neighborhood decay predictors and patient data as needed were geocoded and aggregated to the block group level using ArcGIS 9.3.

[4] Public nuisance properties are properties which property owners have abandoned and failed to maintain.

3.4 Statistical Analysis

Methods

Poisson regressions (Generalized Linear Models) with Poisson distribution and a log link function with random effects for block group was used to assess the overall trends in the three mental health disorders' (mood and anxiety, psychosomatic and substance abuse) hospitalization rate pre (2004) - and post-hurricane (2008 and 2009). The first period was the baseline, 2004 (pre-Katrina), a period regarded as a normal health care system with stable population. The second period, 2008 and 2009 (post-Katrina), is a period when the health care system in the study area was returning to functional or near normal operations (Kates et al. 2006; DeSalvo, Sachs, and Hamm 2008; Stone et al. 2008). As discussed earlier, by 2008, there were 13 of 22 hospitals in operation in the city with 73% of the 2004 population. Years 2005, 2006 and 2007, were excluded to avoid the possible distortion of data due to the "transient" symptoms of affected populations and in this instance health care infrastructure that occurred immediately following a disaster (Adams and Adams 1984).

To better understand trends in mental health hospitalization rates, three models for each mental health disorder were examined for each time period. Poisson regression was also used to assess the relationship between neighborhood and socio-demographic factors and changes in mental health disorders pre- and post- Katrina. The neighborhood socio-demographic and neighborhood physical decay covariates were selected if they significantly predicted the hospitalization rate for each of the three mental health disorders- mood and anxiety, psychosomatic and substance abuse. Pointedly, the models were developed by adding potential neighborhood predictors one by one and retaining those that had significant effects (usually alpha = 0.05- criterion for significance). This is a standard model-building exercise. Wald tests, F-tests, and information criteria (AIC and BIC) were used to make decisions about which predictors to maintain. Socio-demographic predictors were added first, followed by predictors related to neighborhood physical decay.

The Poisson distribution was warranted because the cases of mental health disorders are count data and the counts are quite small (count of the given mental health disorder per block group at a given point in time). The log link ensures that all of the predicted values of the dependent variable will be nonnegative while also accounting for variable risk of exposure. Further, since the response variable does not follow a normal distribution, regular regression is not appropriate. The random effect approach was selected to account for the correlations ("residual" for the block group) resulting from the three observations (each year of study) for each block group, which violates the independence assumption of regression. The choice of random effects for block group (instead of fixed effects) was to conserve power and for computational efficiency. The log of the prevalence rate for each disease is modeled as a linear function of the predictors in order to find the effect of any given predictor.

Descriptive statistics in SPSS were run for initial analyses of frequencies. Regression analyses were undertaken using the R package lme4 (Linear mixed effects), version 0.999375-35. The effect sizes are presented as rate ratio. Results for 2008 and 2009 are reported as post Katrina and results for 2004 are reported as pre-Katrina. Nine models were specified (pre-and post-Katrina), for each of the three mental health disorders with generalized linear mixed model fit by the Laplace approximation. Below are the three specified models for pre-Katrina for each outcome:

- Mood and anxiety mental health hospitalization model, 2004

$$\text{Log}\frac{\pi_j}{P_j} = \beta_o + \beta_1 Persons\ living\ below\ porverty\ level_j + \beta_2 Average\ household\ size_j + \beta_3 Vacant\ housing\ units_j$$

- Stress-related psychosomatic hospitalization model, 2004

$$\text{Log}\frac{\pi_j}{P_j} = \beta_o + \beta_1 Housing\ Units, Census\ 2000_j + \beta_2 Percent\ population\ white_j + \beta_3\ Percent\ population\ male\ _j + \beta_4\ Average\ household\ size_j + \beta_5\ Married\ households\ with\ children_j$$

- Substance abuse mental health hospitalization model, 2004

$$\text{Log}\frac{\pi_{jt}}{P_{jt}} = \beta_o + \beta_1\ Persons\ living\ below\ porverty\ level + \beta_2 Percent\ population\ male_j + \beta_3 Housing\ Units, Census\ 2000_j + \beta_4\ Renter\ cooupied\ housing\ units_j$$

Where π_j is the expected number of cases for block group j at time t, P_j is the population of blockgroup j at time t, and U_j is a normally-distributed random effect for blockgroup j.

3.5 Results

Overall Trends in Mental Health Hospitalizations, pre- and –post Katrina

On the basis of studied data as reported in the LDHH Bureau of Policy Research and Health Systems Analysis, there were 7,470 hospitalizations for mental health disorders between 2004, 2008 and 2009. Psychosomatic disorders accounted for most hospitalizations (46% in 2004 and 43% in 2008. Annual hospitalization rate decreased slightly for mental health disorders from 9.65 per 1000 population pre-Katrina (2004) to 7.13 per 1000 population post-Katrina (2008). Pre-Katrina, patient age ranged from 0-98 years old, with median age of 46 years, but post-Katrina, age ranged from 0-100 years old, and the median age was lower (median 42 years) (Table 3.2).

Table 3.2: Pre-and Post-Katrina Characteristics

	Per-Katrina (2004)	**Post-Katrina (2008)**
*Total Hospitalization cases	3,200	2,017
Annual hospitalization rate per 1000 population	9.65	7.13
Median age (years)	46	42

*Total cases are based on passive surveillance. P=0.000

Table 3.3 presents overall hospitalizations rates for the three mental health disorders in New Orleans by subgroups. Gender, race, poverty, marital status and elderly are all related to hospitalization of the three mental health disorders in the study area at both time points. With the exception of substance abuse hospitalizations (77% males and 23% females), the most frequently occurring hospitalizations was for females (54%) in pre-Katrina New Orleans. Females more than males, were more likely to be hospitalized for mood and anxiety (56% vs. 44%) and psychosomatic stress related disorders (51% vs. 49%). In contrast, males represented 53% of mood and anxiety and 56% of the psychosomatic hospitalizations in post-Katrina New Orleans. As with pre-Katrina rates, substance abuse hospitalizations for males remained higher (78%) post-Katrina.

Notably, hospitalization rate for mood and anxiety among females decreased between 2004 and 2008 from 56% to 47% and for psychosomatic disorders (51% to 46%). Substance abuse hospitalizations among males remained unchanged between 2004 and 2008 (77% vs. 78%).

Single people and African-Americans represented a majority of patients hospitalized for mental health disorders during 2004 and 2008. Pre-Katrina, single people accounted for 65% of all mental health hospitalizations compared to 73% post-Katrina. African-Americans accounted for 59% of stress-related mental health hospitalizations, more than twice the percentage of whites in 2004 (24%) and 57% in 2008 compared to 23%.

Medicaid and Medicare were the major payers for patients hospitalized for mood and anxiety (28% and 23%) and psychosomatic disorders (31% and 28%). Only 12% and 10% of Medicaid and Medicare payments were for substance abuse disorders.

Table 3.3: Hospitalization by subgroups, LDHH Bureau of Policy Research and Health Systems Analysis, 2004 and 2008

Variable	Pre-Katrina (2004)	Post-Katrina (2008)	Result
Mood and Anxiety			
Sex			
Male	44%	53%	Increase
Female	56%	47%	Decrease
Psychosomatic disorders			
Sex			
Male	49%	56%	Increase
Female	51%	44%	Decrease
Substance Abuse			
Sex			
Male	77%	78%	Stable
Female	23%	22%	Stable
Race			
African America	59%	57%	Stable
White	24%	23%	Stable
Marital Status			
Single	65%	73%	Increase
Married	35%	27%	Decrease

Generalized Linear Model Poisson Regression Trends

The overall generalized linear model Poisson regression trend and estimate results for the three outcomes for each block group in the data set pre- and post-Katrina time period are presented in Table 3.4 by year. For the overall trend in mood and anxiety and stress-related psychosomatic hospitalizations, the slope estimates were significant. These models indicated a decrease in hospitalization rate for the two diseases, with an estimated decline rate of 68% from 2004 to 2008 and by 60% from 2004 to 2009 for mood and anxiety. For psychosomatic hospitalizations, the rate decreased by 37% from 2004 to 2008 and by 42% from 2004 to 2009. However, the main time effects were not significant in the substance abuse model, therefore it is not possible to say that there is evidence of change in the overall rate (after controlling for other factors).

Table 3.4: Trends and Estimates for Mental Health Hospitalization for variables 2008 and 2009 relative to 2004

Independent Variable*	**Slope (β)**	**Pr (>|z|)**	**Regression Estimated Rate 2008**	**2009**	**Percent Change**
Mood and Anxiety					
2008	-1.1210	0.000	0.326	~	-0.68
2009	-9.1690	0.000	~	0.400	-0.60
Psychosomatic					
2008	-0.0467	0.029	0.627	~	-0.37
2009	-0.5454	0.006	~	0.580	-0.42
[a] Substance Abuse					
2008	-0.41892	0.181	0.658	~	-0.41
2009	0.18249	0.570	~	1.200	-0.100

* Rows in bold are statistically significant
[a] Main time effects not significant in the substance abuse model
~ Model reported was for independent variable year

Pre-Katrina Mood and Anxiety Mental Health Hospitalizations

Table 3.5 presents the Poisson regression (Generalized Linear Model) results for significant independent variables examined. Significant risk factors for mood and anxiety pre-Katrina included persons living below poverty level, average household size and vacant houses. All variables have a positive correlation. More specifically, when poverty is raised by one unit (percentage), the rate for mood and anxiety is 0.6 percent more and therefore the rate increases by 0.7% for every additional percentage point of poverty. The risk for mood and anxiety hospitalization for those living in larger families as measured by household average size and residents living in neighborhoods with a high percentage of vacant households is 5.6 and 0.7 times that of residents of smaller households and those living in neighborhoods with less vacant houses respectively.

Post-Katrina Mood and Anxiety Mental Health Hospitalizations

Three models are shown in Table 3.5 to illuminate the relation of mood and anxiety hospitalization to neighborhood socio and physical decay factors pre- and post-Hurricane Katrina in the study area. Percent population white, median year structure built and households receiving mail by June 2005 was significantly negatively correlated with hospitalization rate for mood and anxiety. The percentage of households receiving mail in 2005 variable in the mood and anxiety model captures the presence of residents that stayed or returning residents. It could be that residents that stayed or were able to return to the city were healthier pre-Katrina than those unable to return or residents that moved. The risk for mood and anxiety hospitalization for residents in predominately white neighborhoods is 0.997 less than that of non-white neighborhoods.

Risk factors for mood and anxiety hospitalization include percent population living below poverty level, water depth and percentage of completed property demolitions listings. These factors are all positively correlated to hospitalization rate for mood and anxiety. The risk of being hospitalized for mood and anxiety for residents living below poverty level is 0.02 times in 2008 and 0.016 in 2009 that of residents living in affluent neighborhoods. Likewise, the risk is 0.63 times that of residents living in neighborhoods that received the greatest flood impact from Katrina and its 0.79 for residents living in areas that had the highest number of completed demolitions.

Table 3.5: Rate Ratios for mood and anxiety hospitalizations, LDHH Bureau of Policy Research and Health Systems Analysis pre- and Post-Katrina

Risk Factor	Estimate	Std. Error	z-value	P-value	Rate Ratio
Mood and anxiety Pre-Katrina (2004-Baseline)					
Intercept	5.628141	0.291161	-19.330	0.02 *	278.1
[a] Percent Persons in Poverty	0.005941	0.002987	1.989	0.05*	1.006
Average Household Size	0.444560	0.082424	-5.394	0.000***	1.256
Vacant Houses	1.570054	0.402483	3.901	0.000***	4.807
Mood and anxiety Post-Katrina (2008)					
Intercept	17.251730	7.386036	2.336	0.02 *	311
Median Year Structure Built	-0.012792	0.003768	-3.395	0.000***	0.987
[a] Percent Persons in Poverty	0.019744	0.004032	4.896	0.000***	1.020
[b] Water Depth	0.061553	0.026812	2.296	0.02*	1.063
[c] % Completed Demolitions	0.076178	0.014279	5.335	0.000***	1.079
Mood and anxiety Post-Katrina (2009)					
Intercept	-6.6644549	0.1685787	-39.533	0.000***	0.001
[a] Percent Persons in Poverty	0.0160463	0.0038224	4.198	0.000***	1.016
Percent Population White	-0.0031569	0.0015986	-1.975	0.05*	0.997
[d] Households Receiving Mail	-0.0009287	0.0001699	-5.467	0.000***	0.999

[a] Percent persons living below poverty level
[b] Water depth as measured by the flood depth map obtained on August 29th 2005
[c] Completed property demolitions between 2006 through 2009
[d] Households receiving mail by June 2005 as captured by the US Postal Service

A decreasing trend in hospitalization rate for mood and anxiety is observed for neighborhoods that had the highest percentage of white people, newer homes and households receiving mail by June 2005. For example, the risk of mood and anxiety hospitalizations for residents in neighborhoods exhibiting a higher percentage of white people is 0.997 less than that of residents of non-white neighborhoods in 2009.

Pre-Katrina Stress-Related Psychosomatic Hospitalizations

Table 3.6 indicate that overall, residents living in neighborhoods that had less housing units as measured by the Census 2000, had a high percentage of non-white population, females and larger families and single households were more likely to be hospitalized for psychosomatic diseases compared to their counterparts living in neighborhoods with smaller families, more married households with children and male headed households with children.

Post-Katrina Stress-Related Psychosomatic Hospitalizations

Interestingly, none of the variables predict psychosomatic hospitalization, except for percent white and number of housing units as measured by the ACS estimates, and the rate is constant over time. This result suggests that residents of non-white block groups and those residents living in block groups exhibiting a lower number of housing units were more likely to be hospitalized for psychosomatic disorders compared to other racial groups and residents of block groups exhibiting a higher percentage of housing units. Again, the risk of stress-related psychosomatic hospitalization for residents in predominantly white neighborhoods is 0.994 and 0.992 less than that of residents of non-white neighborhoods in 2008 and 2009, respectively (Table 3.6).

Table 3.6: Rate Ratios for stress-related psychosomatic hospitalizations, LDHH Bureau of Policy Research and Health Systems Analysis pre- and Post-Katrina

Predictor	Estimate	Std. Error	z value	P-value	Rate Ratio
Psychosomatic Pre-Katrina					
Intercept	-4.0220000	0.293500	-13.705	0.000***	0.017
Housing Units, ACS estimates	-0.0003259	0.000076	-4.251	0.003***	0.999
Percent Population White	-0.0062930	0.001167	-5.391	0.000***	0.993
Percent Male	-0.0180800	0.004872	-3.711	0.000***	0.982
Average Household Size	-0.1654000	0.070070	-2.361	0.018*	0.847
[a]Married Households	-0.8479010	0.379700	-2.233	0.026*	0.428
Psychosomatic Post-Katrina (2008)					
Intercept	-5.7988245	0.0800144	-72.472	0.000***	0.003
Housing Units, ACS estimates	-0.0003159	0.0001073	-2.944	0.003***	1.000
Percent Population White	-0.0056862	0.0013007	-4.372	0.000***	0.994
Psychosomatic Post-Katrina (2009)					
Intercept	-5.7360000	7.347000	-78.073	0.000***	0.003
Housing Units, ACS estimates	-0.0002412	0.000096	-2.500	0.012*	1.000
Percent Population White	-0.0081160	0.001287	-6.303	0.000***	0.992

[a] Married Households with Children

Pre-Katrina Substance Abuse Mental Health Hospitalizations

The main time effects were not found to be significant in the substance abuse model, therefore it is not possible to say that there is evidence of a change in the overall rate (after controlling for other factors) in substance abuse hospitalizations over time. Risk factors for substance abuse hospitalization included persons living below poverty level, being male and living a rental property. However, the risk is less for those residents living in neighborhoods exhibiting a higher percentage of housing units.

Post-Katrina Substance Abuse Mental Health Hospitalizations

Not surprisingly, risk factors for substance abuse hospitalization post-Katrina include poverty and imminent health threat listed properties (Table 3.7). The risk of being hospitalized for substance abuse for residents living below poverty level is 0.021 times that of residents living in affluent neighborhoods in 2008 and its 0.01 in 2009. The risk is also 0.065 higher for residents of neighborhoods exhibiting poor housing conditions as measured by the presence of imminent health threat listed properties than those living in neighborhoods with less imminent health threat listed properties during the same time period.

Table 3.7: Rate Ratios for substance abuse hospitalizations, LDHH Bureau of Policy Research and Health Systems Analysis pre- and Post-Katrina

Predictor	Estimate	Std. Error	z value	P-value	Ratio
Substance Abuse Pre- Katrina (2004)					
Intercept	-8.0056509	0.2855483	-28.036	0.000***	0.003
[a] Percent Poverty	0.0137705	0.0025088	5.489	0.000***	1.013
Percent Male	0.0145790	0.0048740	2.991	0.002**	1.014
Housing Units, ACS estimates	-0.0005641	0.0001153	-4.893	0.000***	0.999
Renter Occupied Housing	1.4576322	0.1943822	7.499	0.000***	4.295
Substance Abuse Post Katrina (2008)					
Intercept	-6.4602758	0.1499256	-43.090	0.000***	0.002
[a] Percent Poverty	0.0211203	0.0032269	6.545	0.000***	1.021
Percent White	-0.0083684	0.0015772	-5.306	0.000***	0.992
Imminent Health threat Listings	0.0629087	0.0097096	6.479	0.000***	1.065
[b] Households Receiving Mail	-0.0010320	0.0001514	-6.814	0.000***	0.999
Substance Abuse Post Katrina (2009)					
Intercept	-6.3042734	0.1560245	-40.406	0.000***	0.002
[a] Percent Poverty	0.0103872	0.0035809	2.901	0.004***	1.010
Percent Population White	-0.0076504	0.0016757	-4.565	0.000***	0.992
[b] Imminent Health threat Listings	0.0291099	0.0123935	2.349	0.018*	1.030
[c] Households Receiving Mail	-0.0007222	0.0001389	-5.199	0.000***	0.999

[a] Percent persons living below poverty level
[b] Households receiving mail by June 2005 as captured by the US Postal Service
[c] Imminent Health threat property listings

Households receiving mail in 2005 and a higher proportion of white population are negatively associated with substance abuse hospitalizations. The risk for substance abuse hospitalization for residents in predominately white neighborhoods is 0.992 less than that of non-white neighborhoods. Whereas the risk for residents that were receiving mail in 2005 is 0.999 less than that of residents that never received mail during the same time period. Again, the percentage of households receiving mail in 2005 is a proxy for neighborhood characteristics that were operative in 2004. That is, the kind of neighborhood that had a higher number of households receiving mail after Katrina also had a lower hospitalization rate for substance abuse pre-Katrina.

3.6 Discussion

The main finding of this study is that the prevalence of mood and anxiety and psychosomatic disorders has decreased during the three study time frame. However, despite the observed decrease in the two other disorders, there was no statistically significant change in substance abuse hospitalizations during the time points. The present findings seem to be consistent with other research which found mood and anxiety to be the most common mental disorder in the general population (West et al. 2008; Rhodes et al. 2010; Olteanuet al. 2011b). A number of factors may contribute to persistence of mental health disorders in the study area, including ongoing hurricane related stress and subtle long-term effects of hurricane Katrina (e.g. slow neighborhood revitalization, economic pressures due to loss of employment and disruptions in social networks).

One unanticipated finding was the lack of statistically significant change in substance abuse hospitalizations over time. This result differs from those of some published studies (e.g. Boscarino et al. 2004; Vlahov et al. 2004; Boscarino et al. 2005; Cepeda et al. 2010a), although others are in agreement (Boscarino et al. 2005; Knudsen et al. 2005). The observed decrease in substance abuse hospitalization may reflect negative attitudes and beliefs related to seeking professional help for substance abuse and use, or even more frequent underdiagnoses and misdiagnosis of substance abuse disorders.

Poverty is correlated with mood and anxiety and substance abuse hospitalizations at all three time points, including pre-Katrina. Likewise, housing units and whites are correlated with psychosomatic hospitalizations at all three time points, including pre-Katrina. This relationship does not change over time. One explanation could possibly be that poverty and white population and housing units are such strong predictors that after controlling for poverty, population white and the housing units, no other demographic features provide any new information. Another possible explanation could be the effects of Katrina (e.g. resource loss) augmented substance abuse and mood and anxiety hospitalizations.

Surprisingly, males were more likely to be hospitalized for stress-related mood and anxiety and psychosomatic disorders post-Katrina than women but women were overrepresented among patients with mood and anxiety and psychosomatic disorders pre-Katrina. However, men accounted for most of the substance abuse stress-related hospitalizations over time. This finding was unexpected and suggests that men in post-Katrina New Orleans are more likely to seek mental health services overall. Another possible explanation is that men were equally exposed to chronic stressors associated with the disaster such as lower social economic status, loss of employment and income, and that many of these situations may have led to impacts on mental health. This finding also corroborates the ideas of Venegas-Galvez and McMullen-Ladd (2011), who suggested that both genders "may indeed express some symptoms of mental health in different areas of their social functioning and that they tend to express them to different degrees" (Venegas - Galvez and McMullen - Ladd 2011).

Several neighborhood socio-demographic factors were found to be associated with mood and anxiety and psychosomatic disorders overtime. Notably, median year structure built, population white and households receiving mail in 2005had a negative association while persons living below poverty, water depth and completed demolitions are positively associated with mood and anxiety disorders.

Specifically, the rate for mood and anxiety hospitalization decreases in areas that had newer homes, a high percentage of white population and households receiving mail in 2005, but the rate increases in poor neighborhoods, areas that received the highest flood water depth and those areas that had a high percentage of completed demolitions. Not surprisingly, studies have reported "psychological toxins" such as perceived sense of threat, losses and their documented effects to be greater with increasing proximity to the disaster (Guzman-Tapia et al. 2005; Davidson and McFarlane 2006; Cohan 2010). Because the disaster event is a flood, it seems more intuitive that rates would increase among block groups that received the highest water depth because residents of these block groups may have suffered greater loss and stressors. In terms of substance abuse mental health disorders, the independent correlates included poverty, population white, imminent health threat listed properties and households receiving mail in June 2005.

Pre-Katrina, poverty was associated with mood and anxiety and substance abuse hospitalizations. On one hand, living in a large family and in neighborhoods that had a higher number of vacant houses increased the risk for mood and anxiety. On the other hand, being male and living in neighborhoods that had a higher number of renter occupied houses increased the risk for substance abuse hospitalizations. The significant variables in the psychosomatic model have negative effect.

In regards to post-Katrina, results show that residents living in neighborhoods that exhibited a higher percentage of population were less likely to be hospitalized for any of the mental health disorders. Conversely, substance abuse hospitalizations increased with increases in the percentage of imminent health threat properties. There is evidence that poor neighborhood conditions such as increased blighted and abandoned properties (poor-quality housing) can affect people's stress levels that can in turn lead to neighborhood level mental health problems and that improvement in these conditions (e.g. demolitions) can mitigate stress-related mental disorders (Cutrona et al. 2006; Cubbin 2008). Thus, in the present study, it is possible that a high percentage of completed demolitions and a high percentage of dilapidated and imminent health threat properties impose stress on residents, which can lead to substance abuse and use and consequent hospitalization rates.

Quality of housing, like other stratifiers, does not operate in isolation. It interacts in an additive way with other social markers like race and economic status. For example, in this study, poverty is positively related to mood and anxiety and substance abuse hospitalizations. In general, therefore, it seems that residents of more impoverished neighborhoods experienced disproportionately higher hospitalization rates for mood and anxiety and substance abuse disorders compared to residents of wealthy and white neighborhoods. This finding is in agreement with those from a recent study that examined household disrepair and concurrent increases in symptoms of distress among low-income urban women with children (Burdette et al. 2011).

Similarly, living in a newer home was negatively associated with a resident's likelihood of being hospitalized for mood and anxiety disorders. It is likely therefore that those living in older homes were especially vulnerable to the disaster that consequently affected their health outcomes. It should be noted that rates of psychological distress are enhanced in neighborhoods that are characterized by poor neighborhood conditions (Galea et al. 2005; Burdette et al. 2011). This result is also consistent with a study that found an association between more structural damage and injuries to persons living in mobile homes and older housing (Daley et al. 2005).

Residents of predominantly white block groups were less likely to be hospitalized for substance abuse disorders, suggesting that residents of predominantly non-white block groups are more likely to be hospitalized for substance abuse disorders. The latter finding differs from some published studies that utilized self-reported data to assess racial patterns of substance abuse mental health-related disorders (Vaughn et al. 2008; Keller et al. 2010), but is consistent with other studies that relate high substance use and mental health problems for non-whites (Barr et al. 1993; Vogt Yuan 2011). There is also some evidence that blacks and Hispanics exhibit low use of outpatient mental health services (Ojeda and McGuire 2006). Thus, a higher rate can be assumed. This combination of findings provides some support for the conceptual premise that racial disparities in mental health may partly be explained largely by socioeconomic differences (both individual and institutional) that might place individuals at increased risk for both short and long term mental health illnesses.

Additionally, because the variable households receiving mail in 2005 captures residents who either stayed through the disaster or returning residents, it is possible to hypothesize that the prevalence of mood and anxiety and psychosomatic disorders may be lower among residents that stayed or those who are returning and higher in a comparable displaced population.   It is also possible that those residents of households receiving mail in 2009 may have been healthier or that they did not seek mental health services than residents of households that did not receive mail during the same time period.

In all, this study has several methodological limitations. First, the main administrative database from which the three mental health disorders were derived lacked hospital information that feed into the database that could have been used to calculate incidence/prevalence rate. These results therefore need to be interpreted with caution. In addition, data were hospitalizations reported based on passive surveillance in the LDHH Bureau of Policy Research and Health Systems Analysis that includes only cases that were treated in and among New Orleans hospitals. Therefore, it is not possible to analyze the ripple effect on displaced residents of the city post-Katrina, such as those who moved and never returned to the city. In addition, it was not possible to quantify the relative contribution of different sources because case ascertainment by source was not usually reported. Further work is required to establish this.

Secondly, it was assumed that if a household was receiving mail in 2005 that its residents had stayed through Katrina or had returned, however, there was no way of knowing if there were any households that received mail in the same time period that were uninhabited in 2005.

Thirdly, this study relied exclusively on hospital admissions data that could potentially led to selection bias and/or hospital access bias. This type of selection bias is plausible in the current study due to the variation in hospitalizations especially post-Katrina where it's more likely that a disproportionate number of residents with mental health problems were hospitalized in New Orleans hospitals relative to neighboring hospitals. This result may be explained by a number of different factors. For example, it's likely that sick people may have moved out of the city and that those that were able to return to the city are healthier than those unable to return. Further research should be done to investigate the prevalence of mental health among pre-Katrina hurricane residents of the New Orleans and those displaced using hospitalization data as was investigated in Galea et al. (2007) survey study.

Alternatively, it's more than likely that sick people sought care in neighboring parishes and towns and/or that returning sick people with mental health problems did not know where to go to seek mental health services and that, in some instances, many did not seek health care services. Moreover, staff shortages and a crippled health care infrastructure complicated health care accessibility (Ricketts 2005; Kaiser Family Foundation 2006). This finding collaborates Calderon-Abbo (2008) findings, which showed that despite the opening of the acute inpatient and additional acute beds at the South East Louisiana State Hospital, only 14% New Orleans residents sought treatment at the facility in 2006.

Another possible source of selection bias is due to the high number of uninsured patients in the city and few hospitals accepting to treat them (accepting uncompensated care). According to Rudowitz et al. (2006), people with health care needs who originally sought care from Charity Hospital (now closed) turned to Medicaid for assistance and although those who qualified were enrolled, many were denied because of Medicaid's categorical eligibility requirements that requires one to have dependent children (Ross and Wachino 2005; National Center for Disaster Preparedness 2006).

Finally, the accuracy of these data is limited by the methods of data acquisition. For example, not all hospitals report data; that data are based on a moving window that is collected based on hospital licenses and not on precise location of a hospital that treated a patient (e.g. for hospitals with multiple locations). Yet, these data were collected for operational purposes by the Louisiana Bureau of hospitals and as such any relationships that may be detected between the spatial units and disease groupings are likely to be detected in spite of, not due to, issues of data quality. The results from the current study underscore a need to continue surveillance and improve availability of information that could be useful for spatially targeted mental health and intervention programs in New Orleans.

3.7 Conclusion

In summary, this study found that hospitalizations for mood and anxiety and psychosomatic disorders though still prevalent, have decreased over time. The study found no associations between substance abuse disorders and any of the neighborhood and socio-demographic factors overtime. With respect to neighborhood and socio-demographic predictors, the study suggests that a neighborhood recovery variable (households receiving mail), newer homes, population white and housing units are protective factors for mental health disorders.

That neighborhood physical decay variables or structural features (e.g. imminent health properties and competed property demolitions), disaster impact (water depth) and selected socio-demographic variables (e.g. poverty and race) are risk factors for mental health disorders in New Orleans. However, this study had no way of dealing with the selectivity of the post-Katrina population and hospitalization rates among the displaced residents of the city which could not be established; thus, causality cannot be determined. This is an important issue for future research.

Despite the limitations, these sensitivity analyses confirm that neighborhood hazards and exposure to toxics and deleterious neighborhood conditions may influence mental health outcomes for residents of disadvantaged communities or racial groups based on where they live or the nature of their housing (Macintyre et al. 2002; Cohen et al. 2003; Mair et al. 2008; Pollack and Lynch 2009). It is anticipated that the neighborhood and socio-demographic risk factors identified in the current study will be considered in neighborhood revitalization programs focused on reducing the risk factors for mental health in New Orleans and in the development of spatially targeted mental health intervention programs.

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CHAPTER 4

ASSESSMENT AND PREDICTORS OF *CULEX QUINQUEFASCIATUS* ADULT MOSQUITO ABUNDANCE IN POST-KATRINA NEW ORLEANS

4.1 Introduction

Understanding the effects of natural disasters, such as hurricanes and floods on vector mosquito population dynamics is important for implementing disease control measures and in determining which vector species predominate post-disaster and how quickly potential vector populations may develop and recover (Morrow et al. 2010). In particular, hurricanes and floods may act as ecological disturbances that contribute to the collection of stagnant pools or slow-moving water that maybe favorable to vector breeding and increased human exposure (Guzman-Tapia et al. 2005; Cook et al. 2008. A recent study in Belize provides compelling evidence of declining vector abundance immediately after the storm event and a rapid increase in mosquito population post-storm (Morrow et al. 2010). Despite the effects of hurricanes and floods on vector species abundance, few studies have documented their effects on vector-borne disease risk (Campanella 1999; Sanders et al. 1999; Morrow et al. 2010; Guzman-Tapia et al. 2005).

In the continental United States, the effect of flooding caused by the levee failures during hurricanes Katrina on August 29th 2005 and Rita (September 24th, 2005) represents one of the worst disasters in the history of the United States. Of the gulf coast cities affected, the most affected city was the New Orleans metropolitan area which had a storm surge estimated to be near 28 feet (Baldwin 2010). The storm surge led to 53 failures in the federally built levee and flood wall system that surrounded and protected New Orleans. These failures left 80% of the city flooded (Swenson and Marshall 2005). Structural failure of the flood walls along the London Avenue Canal, 17th Street Canal, and the Industrial Canal flooded major residential neighborhoods in the city. Areas farthest closest to the Mississippi River and in low-lying areas including swamp areas were filled with water (Figure 4.1). The water sat in many places for days, creating filth, debris and puddles of standing water that provided suitable breeding conditions for mosquitoes. The immediate mosquito response from the Louisiana state authorities was an evaluation of mosquito problems across the State. Overall, the evaluation revealed that domestic, woodland and floodwater mosquito species presented immediate problems for public health in affected areas. For example, in New Orleans, five such domestic and floodwater mosquito species that were of primary concern to public health included *Cx. quinquefasciatus*, the primary vector for West Nile virus in the United States; *Ae. vexans*, *Ae.sollicitans, Ae. albopictus* and *Ae. aegypti* (McAllister Undated). *Ae. vexans* are of concern because they are a potential vector for West Nile virus (Tiawsirisup et al. 2008), Ae. *Sollicitans* is considered to be the main vector of Eastern Equine Encephalitis virus (EEEv) in coastal areas of eastern US (Rochlin et al. 2009). *Ae. albopictus* an invasive species and *Ae. aegypti* has potential to transmit infectious diseases such as dengue and chikungunya fever (Fischer et al. 2011; Barrera et al. 2011; Moreira et al. 2009; Spiegel et al. 2002).

Consequently, in an effort to control mosquito population, the State of Louisiana initiated a comprehensive aerial mosquito abatement program in New Orleans on September 12th, 2005 (FEMA 2005; Scott 2005). The spraying lasted for about six weeks. However, despite the implemented mosquito control measures, studies conducted in post-Katrina New Orleans report an increase in mosquito abundance in hurricane-affected regions of Louisiana and Mississippi and consequent West Nile neuroinvasive disease (WNND) (Caillouet et al. 2008; Marten et al.

2010). For instance, Caillouet and others compared the number of WNND cases during the 3-week period pre-storm with the number of cases in the 3-week period immediately post- storm to determine whether the number of WNND cases changed immediately post-storm in Louisiana and Mississippi. The researchers observed that WNND incidence in 2006 exceeded the incidence rates in both states during the 2002 epidemic and conclude that " because WNND complications are seen in approximately 1% of WNV infections, a small increase in WNND cases represents a much larger increase in WNV human transmission" increasing public health concern (Caillouet et al. 2008, pg.806)

Previous field studies conducted in Africa, Sweden and the United States have also determined associations between environmental factors such as land cover, temperature and rainfall with both relative mosquito abundance and transmission of mosquito-borne diseases (Beck et al. 1994; Olsson et al. 2005; Parham and Michael 2009; Ruiz et al 2004). For instance, the location of a tract in the Chicago Lake Plain and the amount of vegetation in a census tract resulted in elevated risk of epidemic West Nile virus transmission in the greater Chicago area in 2002 (Ruiz et al. 2004). In an urban setting in the northeastern United States, Brown et al. (2008) found a significant positive correlation between a community of vectors (Cx. pipiens, Cx. restuans, Cx. salinarius, and Ae. vexans) and high resolution imagery derived vegetation indices (NDVI and DWSI). Another study found that although wetland area was not significantly correlated with either vector density, a strong link exists between wetland area and host community composition (Vanessa et al. 2007). Results of several recent studies investigating correlations between weather and mosquito abundance have found similar results. Gilioli and Mariani (2011) found a strong dependence of mosquito population abundance on temperature variation with well-defined site-specific patterns among Kenyan sites. In Seattle, Pecoraro and others (2007) found temperature to be correlated with mosquito abundance but not precipitation.

The goals of the current study are twofold; 1) to examine as to whether mosquito abundance in New Orleans increased or decreased post-disaster and, 2) to examine correlations between neighborhood level, and socio-demographic factors and land cover factors with mosquito abundance. Mosquito abundance refer to the absolute number of mosquitoes (population) caught in the traps.

Figure 4.1: Low-lying areas including swamp areas were filled with water by end of day on August 29th 2005, New Orleans. Source: FEMA

4.2 Materials and Methods

Study Area and Mosquito Surveillance

New Orleans is located in southeastern Louisiana, straddling the Mississippi River, between longitude 90°4′14″W and latitude 29°57′53″N (Figure 4.2). The boundary of the city of New Orleans is conterminous with Orleans Parish though neighboring Jefferson Parish is of similar size and often associated with the city of New Orleans. The lowest point in Louisiana is 8 feet "below" sea level and is located in New Orleans. The average annual rainfall is 62.3 Inches and the maximum and minimum average monthly temperatures are 90.6°F and 41.8°F, respectively. Peak rainfall generally occurs June through September. The city has a population of 343,829 according to the 2010 census. The city has dealt with mosquito-transmitted viral disease since its inception as a French colonial city in 1718. Fortunately, there have been limited cases of WNV in the city. For instance, only 12 cases were reported in 2011 in Louisiana and of these 6 were WNND (Scott-Waldron 2011). The reported cases occurred during the months July, August and September- the expected high-transmission months.

Characteristics of Adult Mosquitos Captured in Gravid Traps

Mosquito surveillance data used in the current study was collected by the city of New Orleans Mosquito and Termite Control Board from September 2005 to September 2010 using gravid traps baited with fish-oil emulsion. The study area had been under entomological surveillance for gravid female mosquitoes looking to deposit their eggs immediately following hurricane Katrina. The entomological surveillance consisted of weekly collections conducted every 3-4 days at traps sparsely located across the city of New Orleans (Figure 4.2). The number of traps varied over time increasing from 7 traps in 2005 to 15 traps in 2006 and 18 in 2010, respectively (see Table 4.1). It was not clear if mosquito surveillance data for year 2007 were ever collected as data could not be obtained from the New Orleans Mosquito Control and Termite Board. It's possible that data may have been lost as some data were archived in paper form only. The number of nights sampled among trap sites also varied from 1 to 37 trap nights (TN). Capture data were normalized, to account for variation in trapping effort, by dividing total capture of the species at each site by the number of TNs for each site, with mean vector density calculated as number of trapped female divided by number of traps in that year.

Table 4.1: Normalized Captures of Post Disaster *Cx. quinquefasciatus* Mosquitoes Vector Species Caught in Gravid Traps and total trap night by site and year, New Orleans, 2006- 2010 by Trap Location

	Normalized mosquito capture			
Site	**2006 (N=330)**	**2008 (N=300)**	**2009 (N=489)**	**2010 (N=383)**
1. 1 Club House Dr (N=107)	89.68	52.70	157.56	59.30
2. 14069 Morrison Rd (N=50)	~	~	55.14	15.00
3. 14638 Claiborne (N=50)	~	236.50	65.82	191.65
4. 2244 Jay St (83)	44.54	6.09	78.52	57.38
5. 2430 S Carrollton Ave (N=81)	40.59	15.59	6.65	16.24
6. 2500 General Degaulle Ave (N=73)	28.95	17.91	148.27	146.76
7. 2312 Louisiana Ave (N=60)	~	32.75	205.10	155.43
8. 3330 Florida Ave (N=47)	~	~	43.54	47.14
9. 3340 General Meyer Ave (N=111)	38.72	74.05	74.48	49.43
10. 3940 Paris Ave (N=67)	~	30.14	30.52	51.71
11. 4550 Old Gentilly Rd (N=26)	~	~	8.89	0.00
12. 5136 Kim Dr (N=76)	65.31	9.36	46.95	12.19
13. 5403 Read Rd (N=47)	~	~	35.15	6.24
14. 6038 St Claude Ave (N=81)	43.50	21.95	154.56	127.40
15. 6500 Magazine St (N=156)	42.65	42.29	98.78	49.29
16. 6900 Downman Rd (N=44)	~	~	41.87	10.81
17. 778 Harrison Ave (N=89)	29.94	43.68	63.10	215.67
18. 987 Robert E Lee Blvd (N=68)	0.00	26.58	21.57	18.48
19. 1441 Basin St (N=33)	52.93	3.89	~	~

~ Trap not yet operational
Year 2007 was not included in the analysis as it was not clear if mosquito surveillance data were ever collected by the New Orleans Mosquito Control and Termite Board.
N- Trap nights

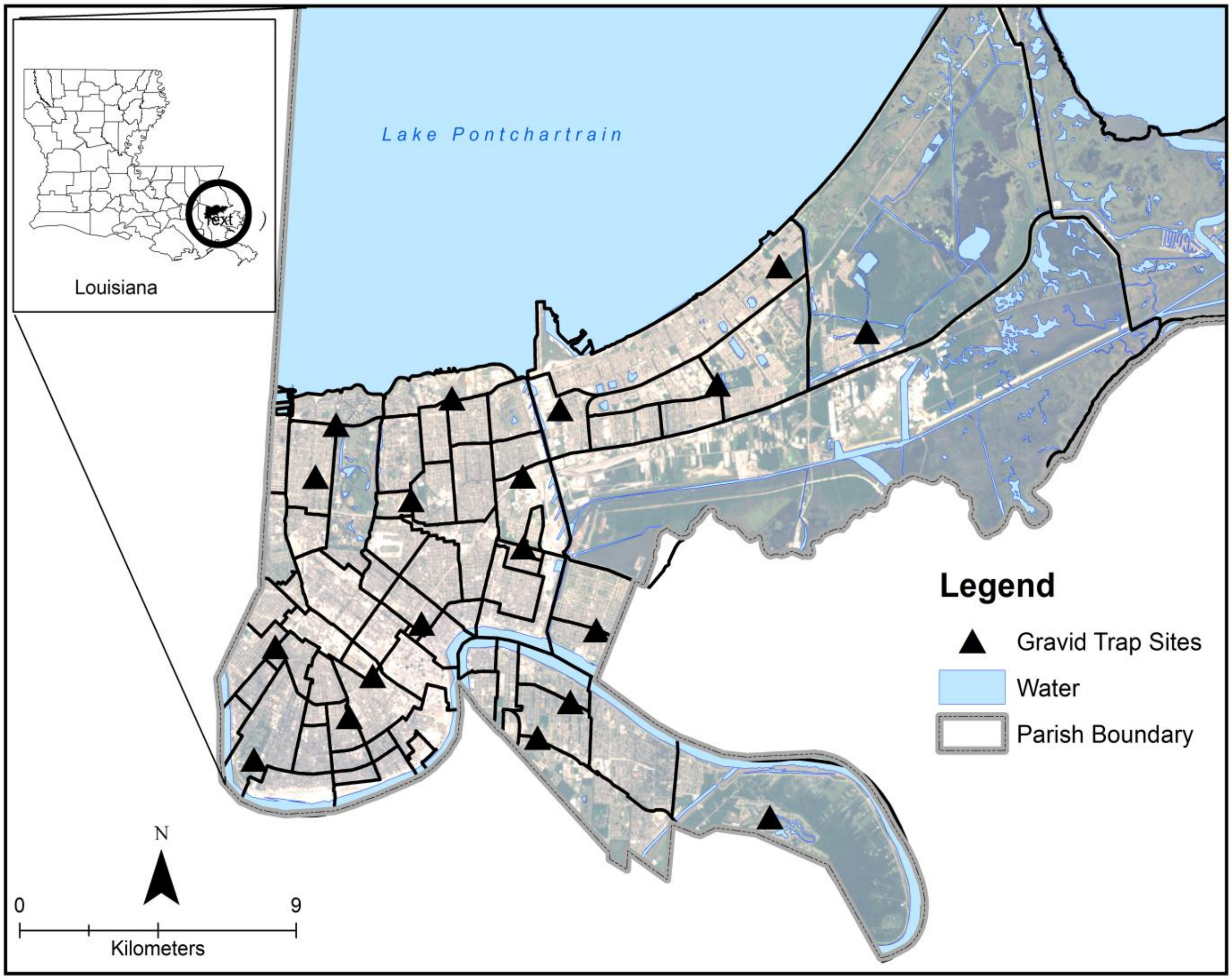


Figure 4.2: **Landsat 7 EMT satellite data (dated September 5th, 2010), spatial resolution 30*30 meters clipped to Orleans Parish Boundary- displayed in true color (band combinations, 3, 2, 1) showing the location of Gravid Traps in 2010, New Orleans.**

Three mosquito species were trapped in gravid traps but due to an inherent bias of gravid traps to collect predominantly *Cx. quinquefasciatus* and their status as a potential arbovirus vector only *Cx. quinquefasciatus* were retained for use in statistical analysis. Moreover, although the two other species *Ae. albopictus* and *Ae. aegypti* are vectors of important pathogens such as dengue and yellow fever (Shroyer 1986), thus far, their ability to serve as efficient vectors for WNV has only been demonstrated in the laboratory (Tiawsirisup et al. 2005; Turell et al. 2005). The number of *Cx. quinquefasciatus* captured per trap night was used as a measure of vector density across traps. Table 4.1 shows the *Cx. quinquefasciatus* annual mean vector density and Table 4.2 illustrates characteristics of each of the mosquitoes captured in gravid traps.

Table 4.2: Gravid Trap Capture Mosquito Characteristics

Species	Host Preference	Activity Time	Flight Range Range	Vector Competence for WNV	Potential to Serve as: Enzootic Vector	Bridge Vector
Cx. Quinquefasciatus	Birds	Night	1 mile	+++	++++	++
Ae. aegypti	Mammals	Day	<.5 mile	+++	0	+
Ae. albopictus	Opportunistic	Day	<.5 mile	++++	+	++++

From Turell, 2005. Efficiency indicated by 0, incompetent +, inefficient ++, efficient +++, very efficient ++++.

Climate Data

Temperature and precipitation data collected at the Louis Armstrong New Orleans International Airport (KMSY) were used for the study (located 10 nautical miles (19 km) west of New Orleans' central business district). Weekly minima and maxima temperatures were averaged from April through August for a total of 23 weeks each year. Total precipitation for each of the 26 weeks was considered. New Orleans has two weather stations that record weekly and daily meteorological measurements within the parish; however, the data from the other weather station do not have complete records during the entire stud period. The Louis Armstrong New Orleans International Airport (KMSY) weather station possessed comprehensive meteorological data, including daily maximum temperature, daily minimum temperature and daily total precipitation.

4.3 Geospatial Analysis of Gravid Trap Habitat Characterization

Using ERDAS Imagine image processing software a September 5th, 2010 classified land cover dataset derived from 30*30 resolution Landsat 7 Enhanced Thematic Mapper (EMT) satellite imagery (essentially cloud free) was used to quantify land cover across traps. Supervised classification was performed to cluster pixels in the subset image data into land cover classes.

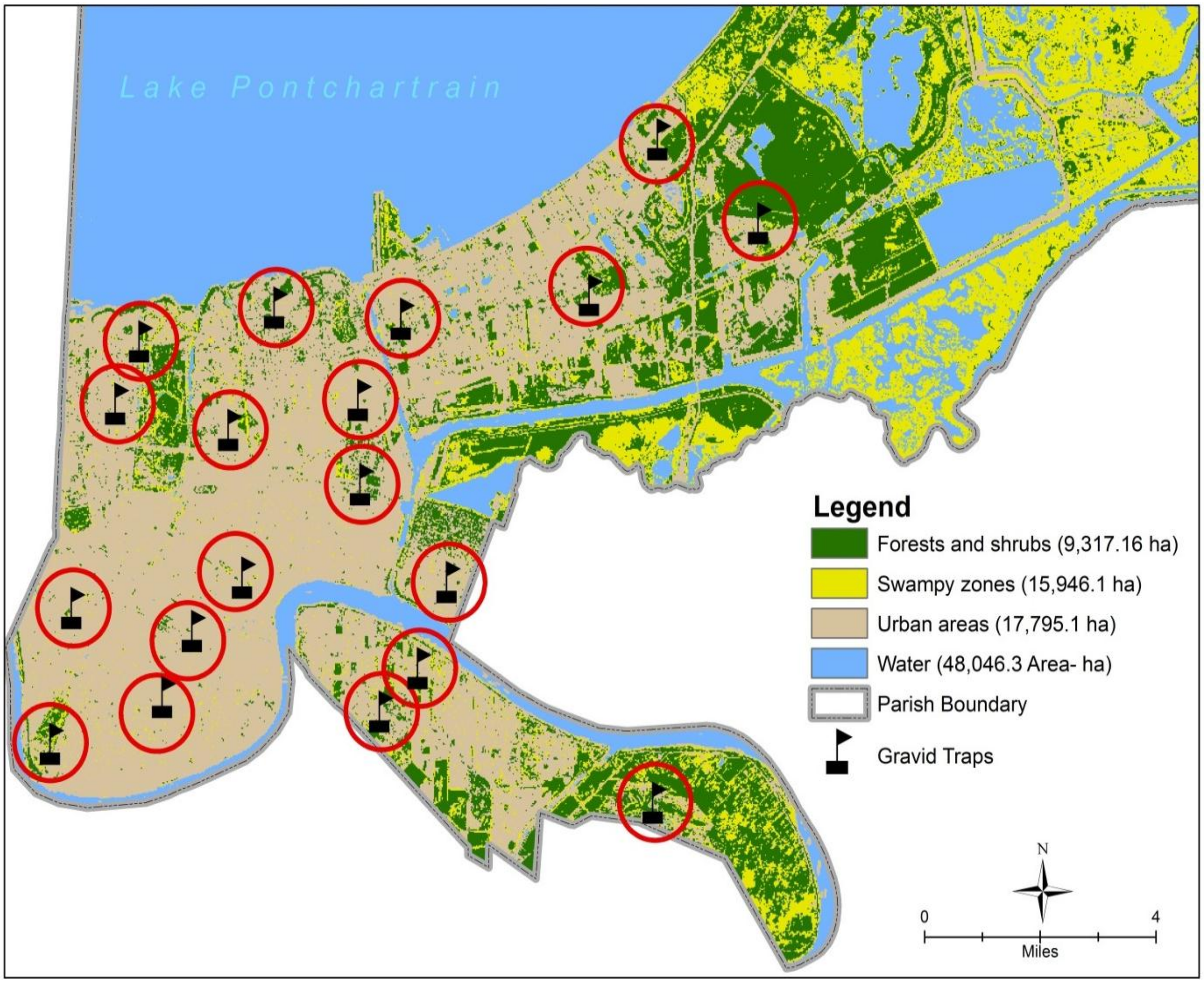


Figure 4.3: Nineteen trap locations where adult mosquitoes were collected from March 2009 to Sept. 2010. The 1-km radius surrounding each trap used in analysis is outlined in red. Traps are overlaid on a land cover/land-use map

This was done by defining regions of interest (ROI) that represented each of the four (4) desired land-use/land-cover classes in the output image corresponding to possible adult *Cx. quinquefasciatus* mosquito habitats in New Orleans. The ROI's included: Forests and shrubs, swampy zones, urban or highly developed areas and water (Figure 4.4; see www.epa.gov/mrlc.nlcd.html for class definitions). Utmost attention was made in selecting ROI's that are homogeneous using and correcting for overlaps between classes. Maximum likelihood classification was performed to assign each pixel in the subset image data to the class that had the highest probability.

4.4 Statistical Analysis

Further, to derive land cover composition around each trap location, a one kilometer buffer was created around each trap (reported average effective flight range of the vector) using ArcGIS, 9.3 (ESRI, Redlands, CA), (Figure 4.3). An area-weighted average was performed to measure the factors for the area covered by each of the trap buffers. The neighborhood and socio-demographic covariates recorded for each trap location were abandoned number of swimming pools, water depth, imminent health threat listed properties, public nuisance property listings, completed property demolitions, population, household income and number of households.

Logistic Regression

Multilevel Logistic regression in R package lme4 (Linear mixed effects) (Bates and Maechler 2009), version 0.999375-35 was used to examine the link between neighborhood, socio-demographic and land cover factors as developed from a supervised classification of LANDSAT image data within a one mile buffer and *Cx. quinquefasciatus* adult mosquito. The model included fixed effects for the year multiplied by month interaction. Random effects were included for trap location. Since there was so much variation in mosquito capture data per trap, two binary variables (dependent variables) were created using the split median function in SPSS (Transform>rank cases>rank types >2). One was whether or not a trap had low mosquito abundance (<= 10 mosquitos) at a given measurement, the other was whether or not a trap had high mosquito abundance (> 50 mosquitos) at a given measurement. The data file had one line per measurement. Since there were multiple measurements per trap per month, the same month/trap combination thus appeared in more than one line in the data file.

Pointedly, one variable has 1 if the trap had low abundance for that measurement and 0 if it was not low. The other variable has 1 if the trap had high abundance for that measurement and 0 if it was not high. If a measurement had medium abundance, the measurement had 0 for both variables. Results for the medium category are not reported as study interest was in assessing areas exhibiting low and high mosquito abundance. Likewise, since the study's focus was on identifying areas exhibiting low and high mosquito abundance, multinomial or ordinal regression is not appropriate, either, particularly because the predictors for low abundance and high abundance are not the same. Neighborhood socio- demographic factors included household income, percent households and population density. Neighborhood decay variable included unattended swimming pools, vacant houses and imminent health threat and public nuisance property listing and completed property demolitions. Land cover variables included variable low, medium and high developed areas (urban areas), forests and shrubs, swampy zones and water.

Repeated Measure of ANOVA

To investigate whether *Cx. quinquefasciatus* adult mosquito abundance changed from 2006 to 2010 (excluding 2007), a repeated measure of ANOVA in PASW Statistics v17.0 .3

(SPSS: An IBM Company) with year as a within-subjects variable and mosquito abundance (trap mosquito count) as a between-subjects was used. Two-tailed tests of probability were employed. Notably, in Repeated Measures ANOVA, the independent variable has categories called levels or related groups. Where measurements are repeated over time, such as when measuring changes in mosquito abundance after hurricane Katrina in current study, the independent variable is time. Each level (or related group) is a specific time point. Hence, for the current study, there would be four time points (2006, 2008, 2009 and 2010) and each time-point is a level of the independent variable. The variable Year 2005 was excluded in the analysis because only two months were sampled encompassing 7 traps. Further, no pre-hurricane Katrina surveillance mosquito data were available thus only post-Katrina mosquito data (and excluding 2007) are used in statistical analysis.

Linear Regression

Secondly, a linear regression method with a backward method was used to examine independent relationships between average mosquito catch per trap night per week and weekly average temperature or precipitation. The backward method was used to eliminate variables that do not significantly enter the regression equation. The dependent variable was *Cx. quinquefasciatus* mosquito abundance per trap and independent variables included mean weekly temperature ^{o}F and weekly precipitation (inches). Statistical tests were performed using PASW Statistics v17.0 .3 (SPSS: An IBM Company).

4.5 Results

Mosquito Abundance

Of the 3 vector species previously documented to be present in New Orleans (Caillouët et al. 2008; Comiskey et al. 1999; Pal and LaChance 1974), *Cx. quinquefasciatus* was by far the most abundant species in all four (4) years. Overall, a total of 62,521female *Cx. quinquefasciatus* mosquitoes were collected from gravid traps over the 4 year time period. Mean adult mosquito abundance is illustrated in Figures 4.4.

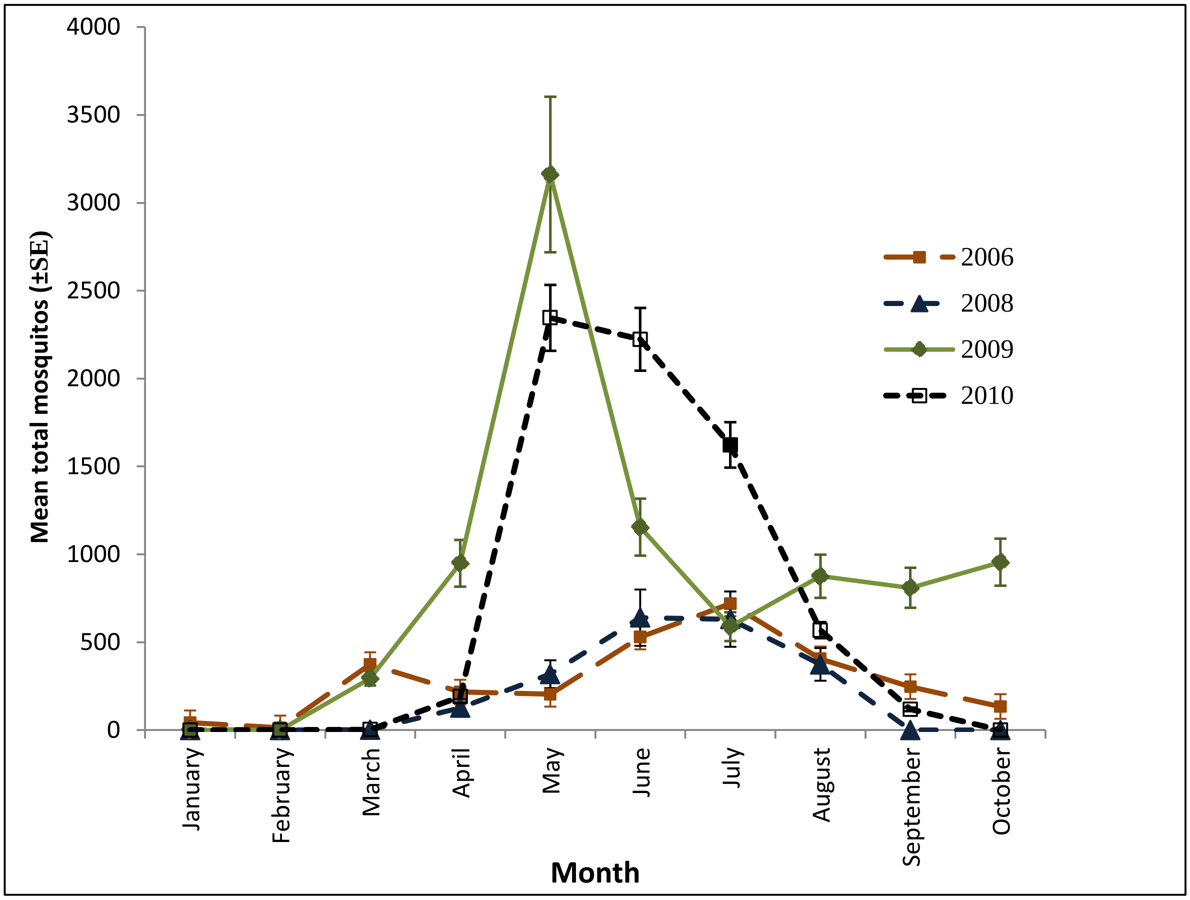


Figure 4.4: Mean adult mosquito abundance of *Cx. quinquefasciatus* from Gravid Traps, September 2006 - September 2010. Error bars are 1 SE. Mean mosquito abundance differed significantly over time periods (F (2.510, 100) = 5.922, P <0.002).

This figure shows that mosquito abundance gradually increased during the summer months (May through August), and peaked in the years 2009 and 2010. More total mosquitos were caught per trap night in 2009 and 2010 relative to 2006 and 2008.

A repeated measures ANOVA with a Greenhouse-Geisser correction determined that mean mosquito abundance differed significantly over time periods ($F(2.510, 100) = 5.922$, $P<0.002$). Multiple comparisons of means indicated that mosquito abundance four years post-disaster increased significantly ($P<0.01$).

Land Cover Trends and Logistic Regression Analysis

Table 4.3 shows results from the logistic regression. Highly developed areas (urbanized areas) are associated with low mosquito abundance in 2008, a little less in 2009 and the association is not statistically significant in 2010. Proximity to large water bodies decreased chances of low abundance in 2009, but made no difference in 2008 or 2010.

Table 4.3: Analysis of locations with low mosquito abundance (<= 10 mosquitos), New Orleans, 2008-2010

Variable	Estimate	Std. Error	z value	Pr (>|z|)
Highly Developed Areas, 2008	14.626759	4.676395	3.128	0.001761 **
Highly Developed Areas, 2009	8.375328	2.776773	3.016	0.002560 **
Highly Developed Areas, 2010	5.270607	3.019321	1.746	0.080876
Year 2008: Water	-6.786985	5.686308	-1.194	0.232648
Year 2009: Water	-20.849534	6.018041	-3.465	0.000531 ***
Year 2010: Water	4.173955	5.418995	0.770	0.441154
Year 2008: Completed Demolitions	-0.007461	0.003732	-1.999	0.045605 *
Year 2009: Completed Demolitions	-0.017868	0.005183	-3.447	0.000566 ***
Year 2010: Completed Demolitions	-0.007062	0.003876	-1.822	0.068485.

***$P<0.000$, **$P< 0.001$, *$P<0.01$. The model included fixed effects for the Year * Month interaction.
The dependent variable was mosquito abundance per trap per month.
Only significant neighborhood predictors were retained.

Likewise, the number of completed demolitions decreases chances of low mosquito abundance in 2009, but not so much in 2008 or 2010. Interestingly, the negative coefficients for completed demolitions means that it was less likely for traps located in areas that had a high number of completed property demolitions to have low mosquito abundance. As a result, if these traps didn't have low mosquito abundance, they must have had medium or high abundance.

Data from Table 4.4 can be compared with the data in Table 4.3 which shows that highly developed areas decreases the chances of high mosquito abundance in 2008, a little less in 2009, and made no difference in 2010. The effect of highly development areas decreases over time. The 2010 finding is slightly different with Figure 4.5 which shows variations in mosquito abundance at sampled traps in 2010. With the exception of completed property demolitions, the neighborhood variables used in this study did not show a statistically significant relationship with high mosquito abundance.

Table 4.4: Analysis of locations with high mosquito abundance (> 50 mosquitos), New Orleans, 2008-2010

Variable	**Estimate**	**Std. Error**	**z value**	**Pr (>|z|)**
Highly Developed Areas, 2008	-21.57020	7.01000	-3.077	0.002091 **
Highly Developed Areas, 2009	-7.21100	3.20214	-2.252	0.024326 *
Highly Developed Areas, 2010	-1.04247	3.39034	-0.307	0.758476

***P<0.000, **P< 0.001, *P<0.01. The model included fixed effects for the Year * Month interaction.
The dependent variable was mosquito abundance per trap per month.
Only significant neighborhood predictors were retained.

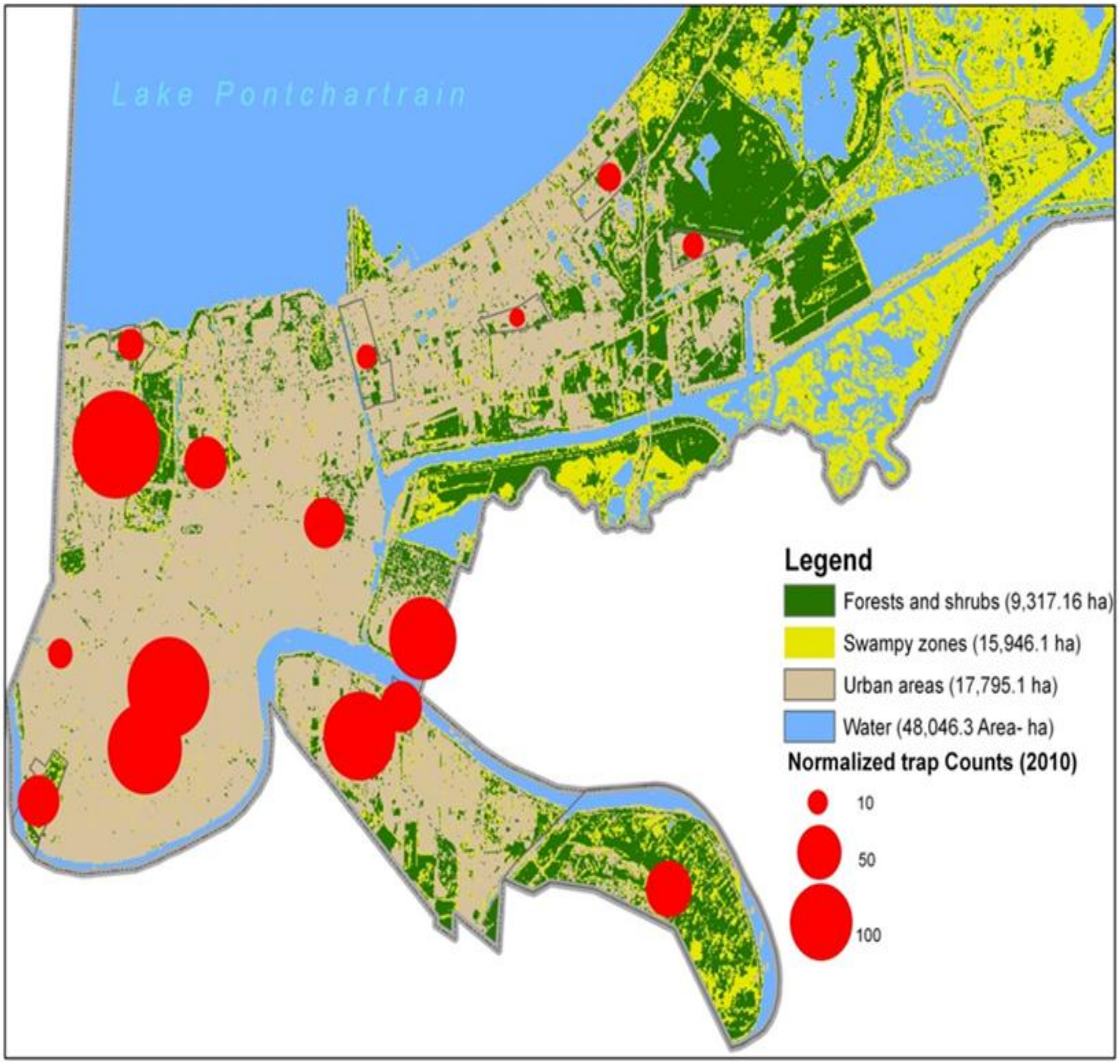


Figure 4.5: Variation in normalized mosquito trap counts at sampled traps, 2010

Weather Trends

Temperature and not rainfall were significant predictors of mosquito abundance in the city of New Orleans, F=2.210, df = 2, 255, P= 0.210 in 2006, F=4.306, df = 2, 269, P= 0.014 in 2008, F=2.329, df = 2, 342, P= 0.099 in 2009 and F=1.664, df = 2, 270, P= 0.191 (Table 4.5, Figure 4.5 and Figure 4.6A-C). The coefficient for mean temperature is .1.314 in 2006, 1.403 in

2008, 2.390 in 2009 and 3.452 in 2010. So for every unit increase in temperature, a 1.314 unit increase in mosquito abundance is predicted in 2006, 1.403 in 2008 and 3.452 in 2009, respectively holding all other variables constant, $P>0.05$. However in 2010, the coefficient for temperature (3.452) is not statistically significant (Table 4.5).

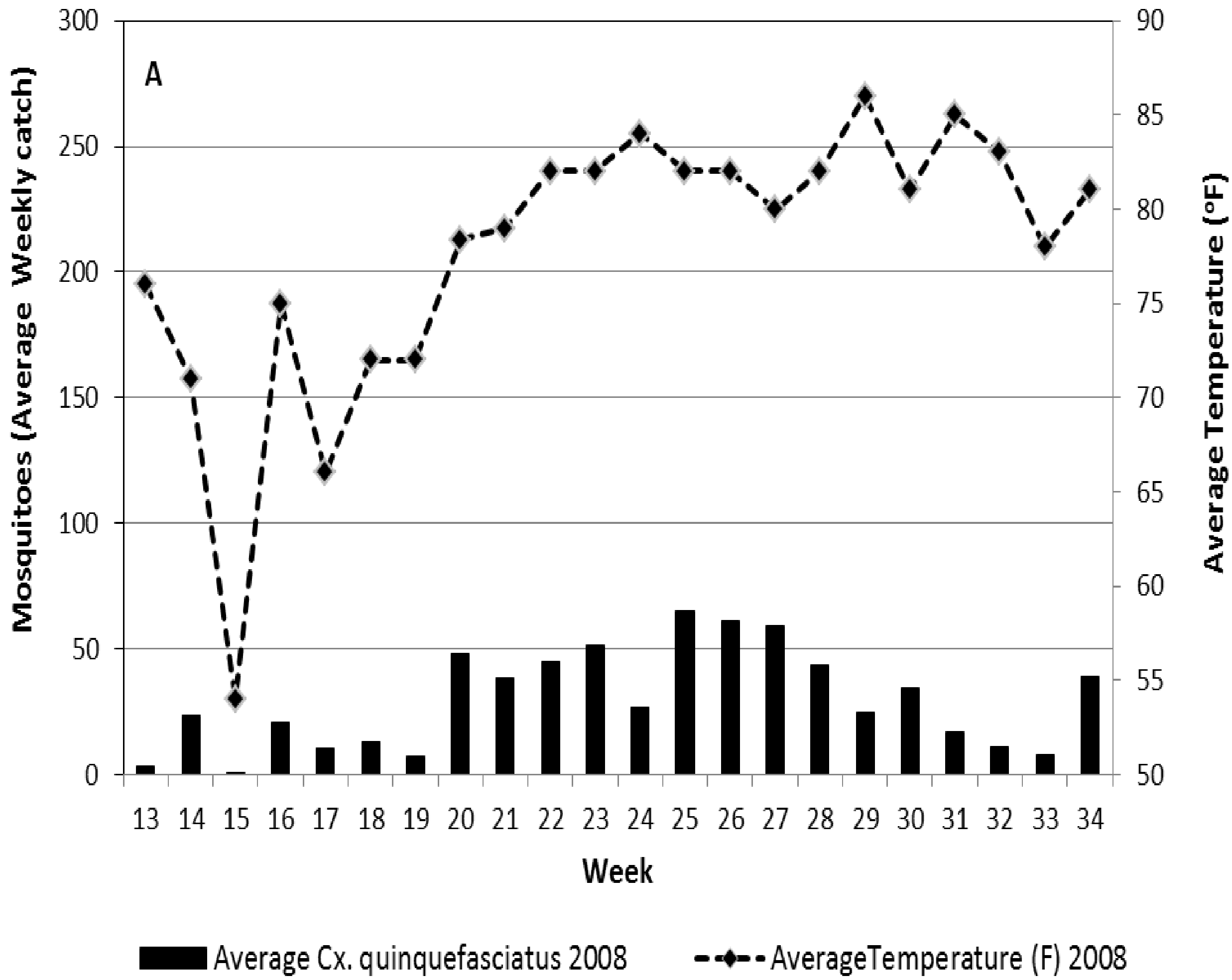
Table 4.5: Partial regression analysis between temperature and vector abundance holding precipitation constant and between precipitation and vector abundance holding temperature constant.

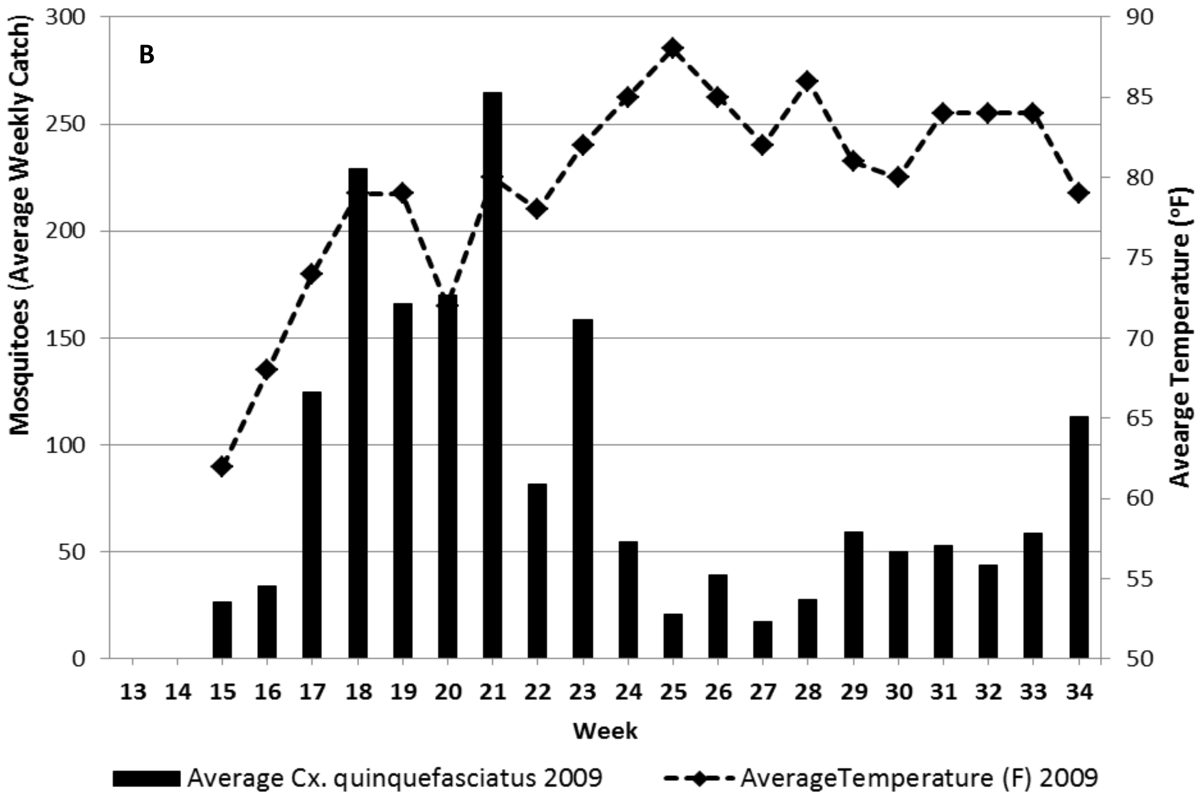
	Coefficients				
	Unstandardized		Standardized		
	B	Std. Error	Beta	t	Sig
Model 1(2006)					
(Constant)	-45.889	48.582		-0.945	0.346
Average Temperature (^{0}F)	1.314	0.651	0.128	2.019	0.045
Precipitation (Inches)	-15.192	15.603	-0.062	-0.974	0.331
Model 1(2008)					
(Constant)	-80.508	40.532		-1.986	0.048
Average Temperature (^{0}F)	1.403	0.518	0.163	2.706	0.007
Precipitation (Inches)	12.395	13.873	0.054	0.893	0.372
Model 1(2009)					
(Constant)	-107.260	94.137		-1.139	0.255
Average Temperature (^{0}F)	2.390	1.228	0.108	1.947	0.052
Precipitation (Inches)	-22.874	16.430	-0.077	-1.392	0.165
Model 1(2010)					
(Constant)	-217.888	190.217		-1.145	0.253
Average Temperature (^{0}F)	3.452	2.328	0.090	1.482	0.139
Precipitation (Inches)	35.090	32.035	0.066	1.095	0.274

Dependent variable is *Cx. quinquefasciatus*

Average weekly precipitation was near zero during temperature peaks across the three years. The correlation between precipitation and mosquitoes was (in 2008 = 0.022, P=0.409; in 2009 = 0.017, P= 0.596 and in 2010 = 0.026, P = 1.69). There was significantly more rainfall in June 2010(17 inches) compared to 2008 (4 inches) and in 2009 (3 inches) and in August 2009

(18 inches) compared to 2008(4 inches) and 2010 (2 inches). Weekly temperature maximum for the 23 weeks from April through August were significantly warmer in 2008, $F=3.043$, $df = 3, 268$, $P= 0.03$ and in 2010, $F=3.469$, $df = 3, 270$, $P= 0.02$. Daily temperature minima fluctuated between 46° F and 84° F.





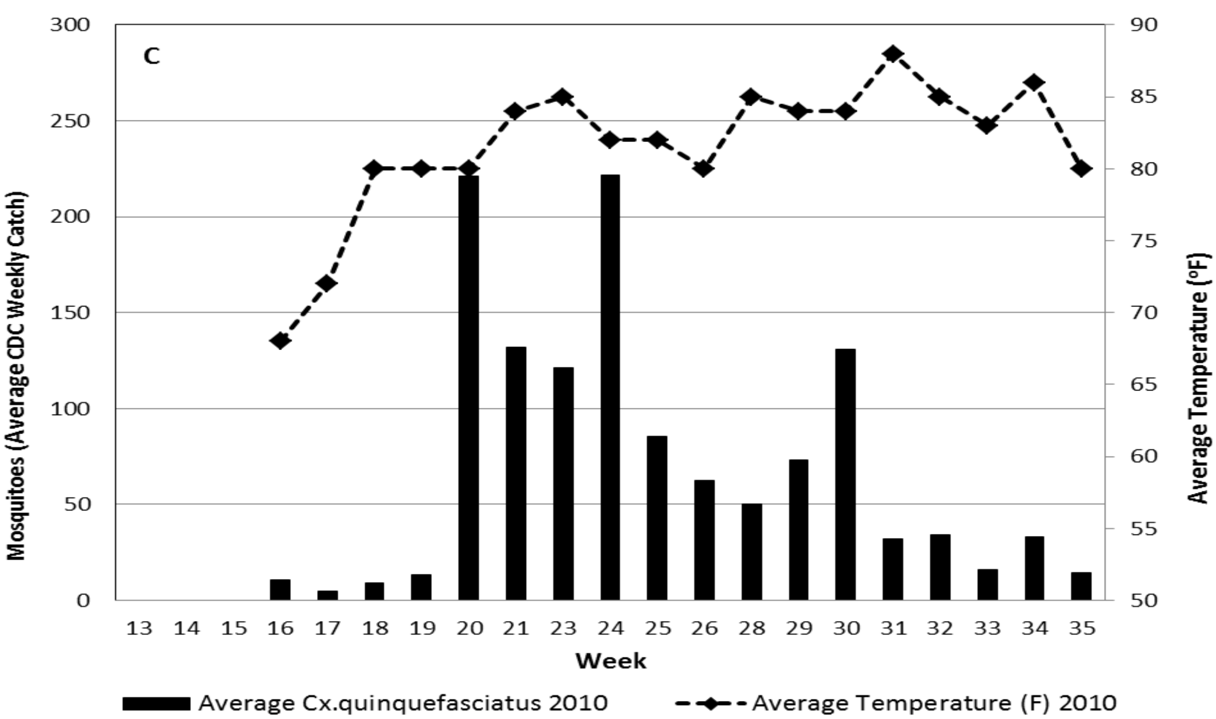


Figure 4.6A-C: Mosquito abundance of West Nile vector species *Cx. quinquefasciatus* in 2008-2010. Note difference in Y-axis. Temperature (^{o}F), Precipitation (mm). Note differences in range of each y-axis.

4.6 Discussion

The present study was carried out to examine whether mosquito abundance in New Orleans increased or decreased post-disaster and to examine correlations between neighborhood level, and socio-demographic factors and land cover factors with mosquito abundance. The number of reported cases of West Nile neuroinvasive disease (WNND) has been reported as sharply increasing in the hurricane-affected regions of Louisiana and Mississippi (Caillouët et al. 2008). The results indicate that mosquito abundance gradually increased during the summer months (May through August), and peaked in the years 2009 and 2010. These findings build on other research that demonstrates the role of initial flood-up in minimizing preferred mosquito-breeding sites (Lindsay et al. 2000; Patz et al. 2003; Morrow et al. 2010). Indeed, the abundance of *Cx. quinquefasciatus* species in the study area has been attributed to the immediate effects of hurricane Katrina that created optimal breeding habitats for the vector (Caillouet 2008; Marten et al. 2010). Distressing marshes of mud, filthy standing puddles, damaged foul-smelling houses and automobiles, and littered swimming pools all provide plentiful oviposition sites for the vector.

Culex species recorded in the present study are the principal mosquito vector of WNV in metropolitan areas (Molaei et al., 2007; Ruiz et al., 2004). Study findings showed a clear correlation between highly developed areas and low *Cx. quinquefasciatus* species abundance. The lower vector species abundance recorded in New Orleans in the present study supports previous research that found highly developed areas in urban areas to typically have low mosquito populations and that central metropolitan areas are significantly less likely to harbor mosquitoes as a result of decreased open space and different economic activities (Kalu et al. 2012; Robert et al. 2003). It is also possible that the implemented mosquito control efforts were successful at reducing disease transmission within the primary vector species of West Nile virus and were likely to have disrupted the amplification cycle of the WNV in the urbanized areas. The findings point to ways in which current host surveillance methodologies may be improved so that effective, targeted and timelier control measures can be implemented. They support continued application of mosquito control efforts in areas where surveillance indicates increased risk of WNV transmission to humans.

The study also found a negative correlation between traps located in close proximity to large water bodies such as flood plains and low mosquito abundance, most likely as a result of the stable high water levels that limit breeding habitats. In contrast, it was less likely for traps located in areas that exhibited a high number of completed property demolitions to have low *Cx. quinquefasciatus* mosquito abundance. There are several possible explanations for this result. One possible explanation is that areas with a high number of completed demolitions had weed-filled vacant lots dotted with puddles of stagnant water providing suitable breeding habitats for the vector (Figure 4.6). Like elsewhere in New Orleans, *Cx. quinquefasciatus* has been found breeding in different water sources and achieving high larval densities in water with high organic content, such as sewage treatment ponds, drains (Calhoun et al. 2007) and in mucky water in abandoned swimming pools (Caillouet et al. 2008; Reisen et al. 2009; Marten et al. 2010).

Because of little variation in weekly mosquito populations per trap, the results do not lead to a simple conclusion regarding the relationship between mosquito abundance and weather. In brief, we conclude that temperature, not rainfall, had a significant effect on *Cx. quinquefasciatus* temporal population dynamics in agreement with findings by Ruiz et al. (2010). This result indicate that our sampling method did not detect a limitation of adult production by accumulation of precipitation in potential breeding sites or a positive association between adult survival and rainfall. Another possible explanation for this result could be that most trap locations sites were had suitable breeding sites year round, without a distinct response to rainfall. Care should be taken when extrapolating results from this study.

Adult mosquito data used in the study analysis were originally collected by the City of New Orleans Mosquito and Termite Control Board as a way to monitor mosquito populations in the study area post-disaster. Unfortunately, since mosquito collections were only made post-disaster and with no pre-disaster mosquito data, pre-disaster effects cannot be assessed. This combination of findings provides some support for the conceptual premise that peaks in mosquito populations post-storm may represent greater public health threat than disease outbreaks (Morrow et al. 2010). Further work is required to establish this.

In conclusion, given how much weather contributes to mosquito abundance relative to other factors, the observed increase in mosquito populations should not be merely attributed to land-use and land cover variables. Barrera and others (Barrera, Amador and MacKay 2011) found rainfall to significantly influence the population of *Cx. quinquefasciatus* in Puerto Rico, while Buckner et al. 2011 found precipitation, temperature, and humidity to be important factors correlated with mosquito abundance in Georgia. However, in this study, there was no significant correlation between mosquito abundance and precipitation and temperature.

Figure 4.7 shows a vacant lot in New Orleans' Lakeview neighborhood. Picture taken in summer 2010 by Imelda Moise

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CHAPTER 5

CONCLUSION

5.1 A One Health Approach

This dissertation has examined the casual pathways through which deteriorating neighborhood conditions have influenced health outcomes for neighborhood residents in post-Katrina New Orleans-an important topic in the context of community recovery following disaster events. A One Health holistic approach to the understanding of disease prevention and the maintenance of humans, animals and neighborhood health has been presented, combining health geography with sociology and urban ecology at an early stage of the study and in the analysis. The approach differs from the traditional public health model (Figure 5.1) that is often sheltered within its specific field in that a One Health illuminates the interconnectedness between human, animal, and environmental health (Figure 5.2) (Cardiff et al. 2008; Eiserink 2007; King et al. 2008). The One Health Approach allowed me to integrate surveillance data from local city departments, the physical environment and data on neighborhood social conditions while using both spatial and non-spatial techniques to illuminate underlying disease risk and areas of increased disease risk and mental health among New Orleans neighborhoods.

To answer my study research questions, interdisciplinary techniques and fine-grained spatial neighborhood level factors related to the natural, built and social-demographic conditions are used to explore neighborhood health risk differentials and implications on neighborhood residents' health outcomes and disease risk. For example, spatial variables describing the physical and socioeconomic neighborhood characteristics hypothesized to influence the presence of unattended swimming pools are identified in order to define areas of persistent problems compared to those that improved. Further, given that area of residence dramatically affects one's health either positively or negatively, the effects of neighborhood conditions on stress-related mental health hospitalizations and on the abundance of the primary vector for West Nile virus is also examined.

The approach and techniques put forth here show encouraging results for a study conducted under challenging conditions and it is logical to assume that improvement in any of the neighborhood conditions discussed may improve mental health of residents or yet decrease mosquito related disease health threats.

This chapter re-examines the results in light of the three chapters (2, 3 and 4) made in this dissertation, discussing the strengths and limitations of each chapter findings. It concludes with an exploration of possible future directions for the research.

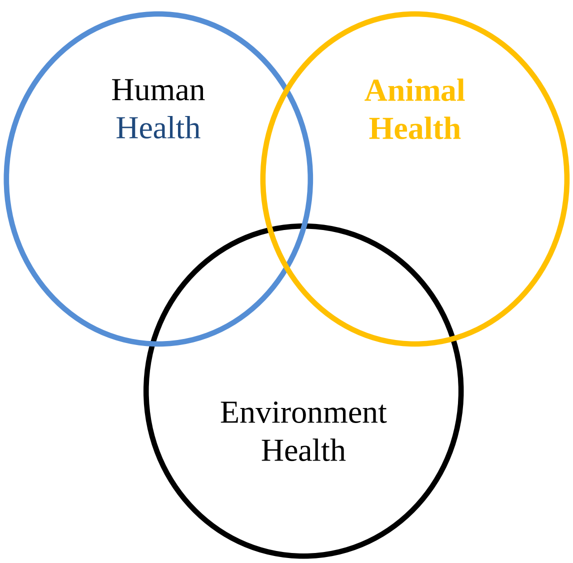

Figure 5.1: Traditional perspective of public health

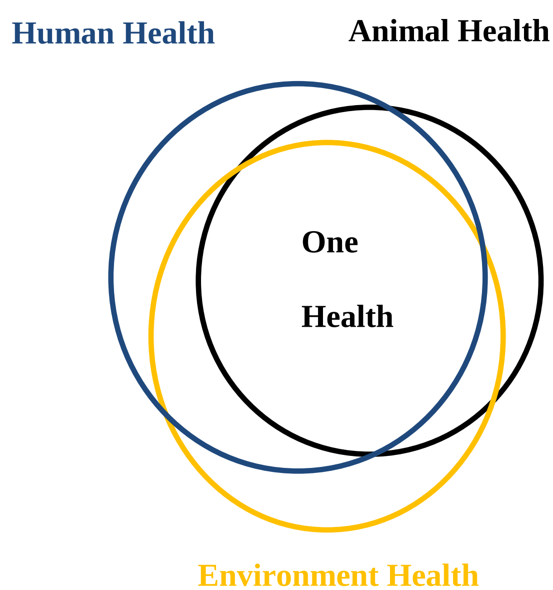

Figure 5.2: One Health approach

5.2 Chapter 2, 3 and 4 Revisited

Chapter 2 set out with the aim of examining the spatial and temporal patterns of unattended swimming pools and determining the effect of neighborhood deterioration on odds of a pool being unattended in the city post-hurricane Katrina, a period during which the city of New Orleans experienced widespread devastation from hurricanes Katrina and Rita. Two techniques were used. The first is a spatial scan statistic and the second are non-spatial techniques that included a multilevel logistic regression and analysis of variance, with a variety of physical neighborhood deterioration risk factors considered for which previous research has shown strong empirical or theoretical support.

One of the more significant findings to emerge from this chapter is that variables associated with neighborhood deterioration (e.g. vacant houses, properties with major structural damages including broken windows) do not provide as robust an explanation for presence of abandoned and unattended swimming pools in New Orleans. It was also shown that block groups with the highest unattended pool density tended to have distinct socioeconomic status and high population density, suggesting that the spatial pattern of unattended pools in New Orleans is, to some degree, a function of economic disparity.

This dissertation chapter raises important questions about how we need to better understand and abate specific neighborhood level factors such as swimming pools that may either inhibit or promote health outcomes of residents. Given that unattended pool characteristics may change based on returning homeowners maintaining their own pools coupled with the NOMTCB's targeted efforts in treating unattended pools in the study area, caution must be taken in concluding that all unattended pools in the study area pose identical health risks. There is, therefore, a definite need for understanding how the problems of unattended pools has happened over time, the intrinsic neighborhood characteristics of how block groups with a higher count of unattended swimming pools have evolved over time need to be explored more carefully.

Chapter 3 was designed to determine the effect of aspects of neighborhood built environment, disaster impact, neighborhood recovery and socio-demographic predictors associated with rates of stress-related mental disorders pre- and post-disaster in the study area. Logistic regression revealed that the hospitalization rates of mood and anxiety and psychosomatic disorders have decreased over time. The following conclusions can be drawn from the present chapter: (1) protective factors for stress-related disorders include water depth, completed demolitions and households receiving mail, and population white whereas (2) risk factors include imminent health properties, older homes, population black and persons living in poverty. More men than women were admitted overall. In general, therefore, it seems that gender, race, marital status and income affected how patients received treatment for stress-related mental disorders.

The current findings add substantially to our understanding of stress-related mental health disorders in the context of community recovery following a disaster event such as hurricanes or floods. Pointedly, a number of factors may contribute to persistence of mental health disorders, including ongoing disaster- related stress and subtle long-term effects of disasters (e.g. slow neighborhood revitalization, economic pressures due to loss of employment and disruptions in social networks). This information can be used to develop targeted interventions aimed at improving returning residents' mental health services and health care infrastructure.

In chapter 4, the aim was to assess land cover and neighborhood predictors that might be linked to the abundance of the *Cx. quinquefasciatus* mosquito species. Different techniques that include image processing, statistics and GIS are used. The results of this investigation show that

GIS and image processing techniques can be used to derive regions of interest (ROI) representing desired land-cover classes in the output image corresponding to possible adult mosquito habitats. Large water bodies, completed property demolitions and highly developed areas emerged as reliable predictors of mosquito abundance. The findings of this study suggest that land cover predicts mosquito abundance in the study area more than neighborhood characteristics. The current findings add to a growing body of literature on vector-borne disease risk associated with disasters. The findings of this chapter have a number of important implications for mosquito control programs.

5.3 Strengths of Current Research

The study has gone some way towards enhancing our understanding of neighborhood effects on health. A major strength of this study was its use of multiple techniques that included both spatial and non-spatial approaches and its use of local city administrative data that are collected as a normal requirement in city operations, as well as Census Bureau data. The data and analysis applied to study the research questions reflect an interdisciplinary approach that provides an alternative to individual survey data collection. In general, therefore, the use of multilevel models together with the spatial scan statistic has enhanced our understanding of neighborhood predictors of stress-related mental health disorders, unattended swimming pools and mosquito abundance in the study area. The Kulldorff spatial scan statistic, in particular, has been known to be exceptional at (1) accounting for the uneven spatial distribution of population densities and cases, (2) its lack of assumptions about cluster size or location (3) its ability to detect multiple clusters and (4) ability to account for multiple testing so that only the maximum possible cluster size is specified.

Taken together, this combination of findings provides some support for the conceptual premise that risk assessment, reduction and transfer are the major elements of risk management. An implication of these findings is that mitigation of foreclosed homes with abandoned pools or mosquito control perhaps should consider the ability of cities to effectively carry out surveillance and mitigation. Moreover, the ability of cities to effectively carry out surveillance and mitigation programs will vary widely from city to city, and may change within a city based on the internal capabilities of the local government and neighborhood residents' spirit of volunteerism.

5.4 Limitations of Current Research

A major weakness in this study is the variation of data used. For example, the analysis of unattended swimming pools and that for mosquito assessment both began post-disaster. Therefore, the current study has only examined the pre- and immediate effects of the hurricane on unattended pools; for mosquito abundance, pre-Katrina mosquito risk in the study area is not assessed. Similarly, in chapter 4, this study had no way of dealing with the selectivity of the post-Katrina population. As a result, mental health hospitalization rates among the displaced residents of the city something which could not be established. Consequently, causality cannot be determined. In the same chapter, data from the US Census ACS 5-year population estimates are relied upon in calculating pre-Katrina hospitalization rates for stress-related mental illness. This can result in either overestimation or underestimation of the pre-Katrina hospitalization rate. In addition, hospital admissions data may be inaccurate in representing prevalence of mental disorders because of selection bias and/or hospital access bias.

Another major limitation can be attributed to the statistical approaches used. First, logistic regression assumes that observations are independent, given the fixed and random effects. In this case, it was assumed that the random effects for block groups are independent. It is also assumed that the random effects for block groups are normally distributed. However, if there are spatial correlations, the independence assumption is violated. Moreover, in the three-year swimming pool model in chapter 2, since the same pools are observed at three time points, the independence of observations assumption is also violated. If a particular pool is unattended in one year, it may be more likely to be unattended in another year as well. Also, despite the many advantages exhibited by the spatial scan statistics, it is prone to exhibit “edge effects”, which can result in biased estimates of unattended risk on the periphery of study block groups. Further, the study makes no distinction between the different types of unattended pool characteristics or condition and how that might have changed overtime- all important components to exposure and risk.

5.5 Future Directions

This research has introduced many questions in need of further investigation. Perhaps the most crucial research needed in dealing with selectivity of the post-Katrina population is conducting a study that estimates stress-related mental health hospitalization rates among the displaced residents of the city. Ideally, assessment of stress-related mental health hospitalization rates among the displaced population might aid in determining causality.

More research is needed to better understand hospitalization rates for those that were treated in and among New Orleans hospitals compared to those treated elsewhere among the displaced populations. Future studies should aim at investigating the prevalence of mental health among pre-Katrina residents as well as analyzing the ripple effect on displaced residents of the city post-Katrina. It is possible that those that moved out of the city and never returned are healthier. One improvement would identify specific hospitals or clinics health services used by both returning and displaced residents and to compare the mental health outcomes for these two groups. This would allow for the exploration of both physical accessibility and geographical coverage of existing mental health services.

An extension to the mosquito paper would involve sampling mosquitoes in multiple traps at one location. This would increase the sensitivity of mosquito surveillance instead of one trap per location as sampled and used in the current study. Having two or more traps at one location would also allow for estimating variation in mosquito trap densities. Also, relating mosquito abundance to actual disease cases may illuminate actual public health disease transmission threat.

Finally, there is great promise in applying the One Health approach in disaster research and emergence preparedness. One Health provides a more comprehensive perspective to disaster research, taking into account the intricate complexities that emerges in the aftermath of disasters. It is possible that the intrinsic neighborhood characteristics that shape high-risk block groups and how they have evolve over time may indeed be explored through the use of diverse vulnerability methods that allow for exploration of why unattended pools or stress-related mental health disorders exist or persist in the study area.

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APPENDIX A

SWIMMING POOL SYNTAX FROM R LME

SYTAXES FOR Swimming Pool Analysis from R LME

```
Library (lme4)
Library (pscl)
library(flexmix)
pools <- read.table("pools-111203.txt", header=T, sep="\t")
stfid <- read.table("pools-stfid.txt", header=T, sep="\t",
colClasses=c('numeric', 'character'), as.is=T)
rownames(stfid) <- as.character(stfid$ID)

# IDs 8 and 68 have pools but no units.
pools <- pools[pools$ID != 8 & pools$ID != 68,]
any((pools$Unattend06 > 0 | pools$Unattend07 > 0 | pools$Unattend08 > 0) &
pools$NPools == 0)

# 120 BGs have no pools
pools <- pools[pools$NPools > 0,]

dim(pools)
sum(is.na(pools))

apply(pools[,c("Unattend06", "Unattend07", "Unattend08", "NPools")], 2, sum)
pools$logNPools <- log(pools$NPools)

###
### Analysis of Unattend06:
###   Poisson regression
###

# Housing characteristics, demographics
summary(m.1 <- glm(Unattend06 ~ MedYrBlt + MedHHInc + POPDENSITY + WaterDepth,
poisson, pools, offset=logNPools))
summary(step(m.1, update(formula(m.1), .~ . +
PCTHISP + PCTWHITE + PCTBLACK + PCTPUBASS + PCTPOV),
direction="forward"))
summary(m.1b <- glm(Unattend06 ~
MedYrBlt + MedHHInc + POPDENSITY + WaterDepth + PCTWHITE,
poisson, pools, offset=logNPools))
```

```
# + Units2000 + POP2000 + TOTPop0509 + HH2000 + HH2005.2009 + PCTCHGHH
summary(step(m.1b, update(formula(m.1b), .~ . +
Units2000 + POP2000 + TOTPop0509 +
HH2000 + HH2005.2009 + PCTCHGHH),
direction="forward"))
summary(m.1c <- glm(Unattend06 ~
MedYrBlt + MedHHInc + POPDENSITY + WaterDepth + PCTWHITE +
PCTCHGHH + HH2005.2009,
poisson, pools, offset=logNPools))

# + IHT2009 + PubNui2010 + DEM06_09 + PCTPubNui2010 + PCTDEM06_09 +
PCTIHT2009
summary(step(m.1c, update(formula(m.1c), .~ . +
IHT2009 + PubNui2010 + DEM06_09 +
PCTPubNui2010 + PCTDEM06_09 + PCTIHT2009),
direction="forward"))
summary(m.1d <- glm(Unattend06 ~
MedYrBlt + MedHHInc + POPDENSITY + WaterDepth + PCTWHITE +
PCTCHGHH + HH2005.2009 + PCTDEM06_09 + IHT2009,
poisson, pools, offset=logNPools))

# + HHMAIL2005 + HHMAIL2008 + HHMAIL2009 + PCTRECMAIL08
summary(step(m.1d, update(formula(m.1d), .~ . +
HHMAIL2005 + HHMAIL2008 + HHMAIL2009 + PCTRECMAIL08),
direction="forward"))
summary(m.1e <- glm(Unattend06 ~
MedYrBlt + WaterDepth + PCTWHITE +
PCTCHGHH + PCTDEM06_09 + IHT2009 + HHMAIL2008,
poisson, pools, offset=logNPools))

# Any stragglers?
summary(step(m.1e, Unattend06 ~
MedYrBlt + MedHHInc + POPDENSITY + WaterDepth +
PCTHISP + PCTWHITE + PCTBLACK + PCTPUBASS + PCTPOV +
Units2000 + POP2000 + TOTPop0509 +
HH2000 + HH2005.2009 + PCTCHGHH +
IHT2009 + PubNui2010 + DEM06_09 +
PCTPubNui2010 + PCTDEM06_09 + PCTIHT2009 +
HHMAIL2005 + HHMAIL2008 + HHMAIL2009 + PCTRECMAIL08,
direction="both"), k=log(356))

# From ground up / top down
summary(step(glm(Unattend06 ~ 1, poisson, pools, offset=logNPools),
Unattend06 ~
MedYrBlt + MedHHInc + POPDENSITY + WaterDepth +
```

```
PCTHISP + PCTWHITE + PCTBLACK + PCTPUBASS + PCTPOV +
Units2000 + POP2000 + TOTPop0509 +
HH2000 + HH2005.2009 + PCTCHGHH +
IHT2009 + PubNui2010 + DEM06_09 +
PCTPubNui2010 + PCTDEM06_09 + PCTIHT2009 +
HHMAIL2005 + HHMAIL2008 + HHMAIL2009 + PCTRECMAIL08,
direction="both"), k=log(356))
summary(step(glm(Unattend06 ~
MedYrBlt + MedHHInc + POPDENSITY + WaterDepth +
PCTHISP + PCTWHITE + PCTBLACK + PCTPUBASS + PCTPOV +
Units2000 + POP2000 + TOTPop0509 +
HH2000 + HH2005.2009 + PCTCHGHH +
IHT2009 + PubNui2010 + DEM06_09 +
PCTPubNui2010 + PCTDEM06_09 + PCTIHT2009 +
HHMAIL2005 + HHMAIL2008 + HHMAIL2009 + PCTRECMAIL08,
poisson, pools, offset=logNPools),
direction="both"), k=log(356))
```

 # Final Model

```
summary(m.1f <- glm(Unattend06 ~
MedYrBlt + WaterDepth + PCTWHITE + Units2000 +
PCTCHGHH + PCTDEM06_09 + IHT2009 + PCTRECMAIL08,
poisson, pools, offset=logNPools))
summary(m.1f. <- glm(Unattend06 ~
MedYrBlt + WaterDepth + PCTWHITE + Units2000 +
PCTCHGHH + PCTDEM06_09 + IHT2009 + PCTRECMAIL08,
quasipoisson, pools, offset=logNPools))
summary(m.1f.. <- glmer(Unattend06 ~
MedYrBlt + WaterDepth + PCTWHITE + Units2000 +
PCTCHGHH + PCTDEM06_09 + IHT2009 + PCTRECMAIL08 + (1|ID),
pools, poisson, offset=logNPools))

###
### Analysis of Unattend06:
###   Zero-Inflated Poisson model
###

summary(m.2a <- zeroinfl(Unattend06 ~
WaterDepth + PCTWHITE + Units2000 +
PCTCHGHH + PCTDEM06_09 + IHT2009 + PCTRECMAIL08 |
WaterDepth,
pools, dist="poisson", offset=logNPools))
AIC(m.2a)

summary(m.2b <- zeroinfl(Unattend06 ~
WaterDepth + PCTWHITE + Units2000 +
```

```
PCTCHGHH + PCTDEM06_09 + IHT2009 + PCTRECMAIL08 |
MedYrBlt + MedHHInc,
pools, dist="poisson", offset=logNPools))
AIC(m.2b)

summary(m.2c <- zeroinfl(Unattend06 ~
WaterDepth + PCTWHITE + PCTBLACK + Units2000 +
PCTCHGHH + PCTDEM06_09 + PCTRECMAIL08 |
MedYrBlt + MedHHInc,
pools, dist="poisson", offset=logNPools))
AIC(m.2c)

###
### Analysis of Unattend06:
###   Mixture Poisson model
###

m.3a <- stepFlexmix(Unattend06 ~
MedYrBlt + WaterDepth + PCTWHITE + Units2000 +
PCTCHGHH + PCTDEM06_09 + IHT2009 + PCTRECMAIL08,
model=FLXMRglmfix(family="poisson", offset=pools$logNPools),
cluster=(pools$Unattend06>3)+1,
data=pools, k=2, nrep=5)
###
### Analysis of Unattend06:
###   Logit Model
###

summary(m.4a <- glm(cbind(Unattend06, NPools-Unattend06) ~
MedYrBlt + WaterDepth + PCTWHITE + Units2000 +
PCTCHGHH + PCTDEM06_09 + IHT2009 + PCTRECMAIL08,
binomial, pools))

summary(m.4b <- glmer(cbind(Unattend06, NPools-Unattend06) ~
MedYrBlt + WaterDepth + PCTWHITE + Units2000 +
PCTCHGHH + PCTDEM06_09 + IHT2009 + PCTRECMAIL08 + (1|ID),
pools, binomial))

summary(m.4c <- glmer(cbind(Unattend06, NPools-Unattend06) ~
MedYrBlt + WaterDepth + PCTWHITE + PCTCHGHH + PCTDEM06_09 +
(1|ID), pools, binomial))

summary(m.4d <- glmer(cbind(Unattend06, NPools-Unattend06) ~
MedYrBlt + WaterDepth + PCTWHITE + PCTCHGHH + PCTDEM06_09 +
WaterDepth:MedYrBlt + (1|ID), pools, binomial))
```

```
noFlood <- (pools$WaterDepth == 0)*1
summary(m.4e <- glmer(cbind(Unattend06, NPools-Unattend06) ~ WaterDepth +
MedYrBlt*noFlood +
PCTWHITE*noFlood + PCTCHGHH*noFlood + PCTDEM06_09*noFlood +
(1|ID), pools, binomial))

###
### Analysis of Unattend06:
###   Logit Model, only those block groups with unattended pools
###

summary(m.5a <- glm(cbind(Unattend06, NPools-Unattend06) ~
MedYrBlt + WaterDepth + PCTWHITE + Units2000 +
PCTCHGHH + PCTDEM06_09 + IHT2009 + PCTRECMAIL08,
binomial, pools, subset=(pools$Unattend06>0)))

summary(m.5b <- glmer(cbind(Unattend06, NPools-Unattend06) ~
MedYrBlt + WaterDepth + PCTWHITE + Units2000 +
PCTCHGHH + PCTDEM06_09 + IHT2009 + PCTRECMAIL08 + (1|ID),
pools, binomial, subset=(pools$Unattend06>0)))

# cf m.4c
summary(m.5c <- glmer(cbind(Unattend06, NPools-Unattend06) ~
MedYrBlt + WaterDepth + PCTWHITE + PCTCHGHH + PCTDEM06_09 +
(1|ID), pools, binomial, subset=(pools$Unattend06>0)))

###
### Analysis of Unattend06:
###   Logit Model for having any unattended pools
###

anyUnattend06 <- (pools$Unattend06 > 0)*1

summary(m.6a <- glm(anyUnattend06 ~ NPools + WaterDepth +
MedYrBlt + PCTWHITE + PCTBLACK,
binomial, pools))
summary(step(m.6a, update(formula(m.6a), .~ . +
Units2000 + POP2000 + TOTPop0509 +
HH2000 + HH2005.2009 + PCTCHGHH),
direction="forward"))

summary(m.6b <- glm(anyUnattend06 ~ NPools + WaterDepth +
MedYrBlt + PCTWHITE + PCTBLACK + HH2000,
binomial, pools))
summary(step(m.6b, update(formula(m.6b), .~ . +
IHT2009 + PubNui2010 + DEM06_09 +
```

```
PCTPubNui2010 + PCTDEM06_09 + PCTIHT2009),
direction="forward"))

summary(m.6c <- glm(anyUnattend06 ~ NPools + WaterDepth +
MedYrBlt + PCTWHITE + PCTBLACK + HH2000 + PCTDEM06_09,
binomial, pools))
summary(step(m.6c, update(formula(m.6c), .~ . +
HHMAIL2005 + HHMAIL2008 + HHMAIL2009 + PCTRECMAIL08),
direction="forward"))

# From ground up / top down
summary(step(glm(anyUnattend06 ~ NPools, binomial, pools),
anyUnattend06 ~ NPools + MedYrBlt + MedHHInc + POPDENSITY + WaterDepth +
PCTHISP + PCTWHITE + PCTBLACK + PCTPUBASS + PCTPOV + Units2000 + POP2000 +
TOTPop0509 + HH2000 + HH2005.2009 + PCTCHGHH +
IHT2009 + PubNui2010 + DEM06_09 +
PCTPubNui2010 + PCTDEM06_09 + PCTIHT2009 +
HHMAIL2005 + HHMAIL2008 + HHMAIL2009 + PCTRECMAIL08,
direction="both"))

summary(step(glm(anyUnattend06 ~ NPools + MedYrBlt + MedHHInc + POPDENSITY +
WaterDepth + PCTHISP + PCTWHITE + PCTBLACK + PCTPUBASS + PCTPOV +
Units2000 + POP2000 + TOTPop0509 + HH2000 + HH2005.2009 + PCTCHGHH +
IHT2009 + PubNui2010 + DEM06_09 + PCTPubNui2010 + PCTDEM06_09 + PCTIHT2009 +
HHMAIL2005 + HHMAIL2008 + HHMAIL2009 + PCTRECMAIL08, binomial, pools),
direction="both"))
```

 # Final model

```
summary(m.6d <- glm(anyUnattend06 ~ NPools + WaterDepth +
MedYrBlt + PCTBLACK + HH2000 + DEM06_09,
binomial, pools))

# MedYrBlt + MedHHInc + POPDENSITY + WaterDepth
# PCTHISP + PCTWHITE + PCTBLACK + PCTPUBASS + PCTPOV
# Units2000 + POP2000 + TOTPop0509 + HH2000 + HH2005.2009 + PCTCHGHH
# IHT2009 + PubNui2010 + DEM06_09 + PCTPubNui2010 + PCTDEM06_09 + PCTIHT2009
# HHMAIL2005 + HHMAIL2008 + HHMAIL2009 + PCTRECMAIL08

###
### Analysis through Time:
###   Logit Model (cf. m.4c)
###

summary(glmer(cbind(Unattend07, NPools-Unattend07) ~
MedYrBlt + WaterDepth + PCTWHITE + PCTCHGHH + PCTDEM06_09 +
```

```
(1|ID), pools, binomial))
summary(glmer(cbind(Unattend08, NPools-Unattend08) ~
MedYrBlt + WaterDepth + PCTWHITE + PCTCHGHH + PCTDEM06_09 +
(1|ID), pools, binomial))

poolsT <- rbind(pools, pools, pools)
poolsT$Time <- factor(rep(c("Y06", "Y07", "Y08"), each=dim(pools)[1]))
poolsT$Unattend <- c(pools$Unattend06, pools$Unattend07, pools$Unattend08)

summary(glmer(cbind(Unattend, NPools-Unattend) ~ Time +
MedYrBlt + WaterDepth + PCTWHITE + PCTCHGHH + PCTDEM06_09 +
(1|ID), poolsT, binomial))
summary(m.7a <- glmer(cbind(Unattend, NPools-Unattend) ~ Time +
WaterDepth + PCTWHITE + PCTCHGHH + PCTDEM06_09 + # MedYrBlt +
(1|ID), poolsT, binomial))

summary(glmer(cbind(Unattend, NPools-Unattend) ~ Time +
WaterDepth + PCTWHITE*Time + PCTCHGHH + PCTDEM06_09 +
(1|ID), poolsT, binomial))

summary(glmer(cbind(Unattend, NPools-Unattend) ~ Time +
WaterDepth + PCTWHITE + PCTCHGHH*Time + PCTDEM06_09 +
(1|ID), poolsT, binomial))

summary(glmer(cbind(Unattend, NPools-Unattend) ~ Time +
WaterDepth + PCTWHITE + PCTCHGHH + PCTDEM06_09*Time +
(1|ID), poolsT, binomial))

summary(m.7b <- glmer(cbind(Unattend, NPools-Unattend) ~ Time +
WaterDepth*Time + PCTWHITE + PCTCHGHH + PCTDEM06_09 + # MedYrBlt +
(1|ID), poolsT, binomial))

summary(m.7c <- glmer(cbind(Unattend, NPools-Unattend) ~ Time +
WaterDepth*Time + PCTWHITE + PCTCHGHH + PCTDEM06_09 + # MedYrBlt +
(0+Time|ID), poolsT, binomial))

deviance(m.7b)-deviance(m.7c)  # Extra RVs seem justified, despite stderrs

#write.table(data.frame(ID=rownames(ranef(m.7c)[[1]]),
#                  STFID=stfid[rownames(ranef(m.7c)[[1]]),"STFID"],
#                  ranef(m.7c)[[1]]),
#          file='/tmp/bg-effects-111208.txt', row.names=F, sep='\t', quote=F)

###
### Analysis through Time:
###   Logit model with scan clusters
```

```
###

clusters <- read.table("ScanClusters-spatial-111208.txt", header=T, sep='\t',
colClasses=c('character', rep('numeric', 10)), as.is=T)
rownames(clusters) <- clusters$STFID

dim(clusters)
table(clusters$CLUSTER)

sum(stfid[as.character(pools$ID),"STFID"] %in% clusters$STFID)
all(clusters$STFID %in% stfid[as.character(pools$ID),"STFID"])
clusters$STFID[!(clusters$STFID %in% stfid[as.character(pools$ID),"STFID"])]
# But 220710017227 was excluded because it has no pools!

pools$cluster <- clusters[stfid[as.character(pools$ID),"STFID"],"CLUSTER"]
pools$cluster[pools$cluster > 2] <- 3
pools$cluster[is.na(pools$cluster)] <- 0
table(pools$cluster)
pools$cluster <- factor(pools$cluster)
poolsT$cluster <- rep(pools$cluster, 3)

### Note: I DO NOT believe that these results are appropriate!

summary(m.8a <- glmer(cbind(Unattend, NPools-Unattend) ~ Time +
WaterDepth*Time + PCTWHITE + PCTCHGHH + PCTDEM06_09 +
cluster + (0+Time|ID), poolsT, binomial))

summary(m.8b <- glmer(cbind(Unattend, NPools-Unattend) ~ Time +
WaterDepth*Time + PCTWHITE + PCTCHGHH + PCTDEM06_09 +
cluster*Time + (0+Time|ID), poolsT, binomial))

pchisq(deviance(m.8a)-deviance(m.8b), 6, lower.tail=F)

summary(glm(I(cluster == 1) ~ NPools + WaterDepth +
PCTWHITE + TOTPop0509 + MedHHInc, binomial, pools))
```

APPENDIX B

MENTAL HEALTH SYNTAX FROM R LME

 # Post-Katrina specified models by year

```
library(lme4)

hosp <- read.table('hospitalization.txt', header=T, sep='\t')

hosp$Pop[hosp$Time == 2008] <- hosp$Pop2008[hosp$Time == 2008]
hosp$Pop[hosp$Time == 2009] <- hosp$Pop2009[hosp$Time == 2009]
hosp$lPop <- log(hosp$Pop)

hosp.mood <- subset(hosp, hosp$Disease=='Mood and Anxiety' & hosp$Pop > 0)
hosp.psychosomatic <- subset(hosp, hosp$Disease=='Psychosomatic' & hosp$Pop > 0)
hosp.abuse <- subset(hosp, hosp$Disease=='Substance Abuse' & hosp$Pop > 0)
```

Mood and Anxiety Hospitalizations

```
summary(m.final <- glmer(Count ~ Time + (1|BG) + MedYrBlt + PCTPOV +
PCTWHITE*Time + WaterDepth*Time + PCTDEM06_09*Time + HHMAIL2005*Time,
hosp.mood, poisson, offset=hosp.mood$lPop))

summary(m.2008a <- glm(Count ~ MedYrBlt + PCTPOV + PCTWHITE + WaterDepth +
PCTDEM06_09 + HHMAIL2005, poisson, hosp.mood, offset=hosp.mood$lPop,
subset=(hosp.mood$Time==2008)) )

summary(m.2008 <- glm(Count ~ MedYrBlt + PCTPOV + WaterDepth + PCTDEM06_09,
poisson, hosp.mood, offset=hosp.mood$lPop, subset=(hosp.mood$Time==2008)) )

summary(m.2009a <- glm(Count ~ MedYrBlt + PCTPOV + PCTWHITE + WaterDepth +
PCTDEM06_09 + HHMAIL2005, poisson, hosp.mood, offset=hosp.mood$lPop,
subset=(hosp.mood$Time==2009)) )

summary(m.2009 <- glm(Count ~ PCTPOV + PCTWHITE + HHMAIL2005, poisson,
hosp.mood, offset=hosp.mood$lPop, subset=(hosp.mood$Time==2009)) )
```

Psychosomatic Hospitalizations

```
summary(p.final <- glmer(Count ~ Time + (1|BG) + Units2000 + PCTWHITE,
hosp.psychosomatic, poisson, offset=hosp.psychosomatic$lPop))
```

```
summary(p.2008 <- glm(Count ~ Units2000 + PCTWHITE, poisson, hosp.psychosomatic,
offset=hosp.psychosomatic$lPop, subset=(hosp.psychosomatic$Time == 2008) ))

summary(p.2009 <- glm(Count ~ Units2000 + PCTWHITE, poisson, hosp.psychosomatic,
offset=hosp.psychosomatic$lPop, subset=(hosp.psychosomatic$Time == 2009) ))
cbind(coef(p.2004), coef(p.2008), coef(p.2009))
```

Substance Abuse

```
summary(a.final <- glmer(Count ~ Time + (1|BG) + PCTPOV:Time + PCTWHITE:Time +
IHT2009:Time + HHMAIL2005:Time, hosp.abuse, poisson, offset=hosp.abuse$lPop))

summary(a.2008 <- glm(Count ~ PCTPOV + PCTWHITE + IHT2009 + HHMAIL2005,
poisson, hosp.abuse, offset=hosp.abuse$lPop, subset=(hosp.abuse$Time == 2008) ))

summary(a.2009 <- glm(Count ~ PCTPOV + PCTWHITE + IHT2009 + HHMAIL2005,
poisson, hosp.abuse, offset=hosp.abuse$lPop, subset=(hosp.abuse$Time == 2009) ))
cbind(coef(a.2004a), coef(a.2008), coef(a.2009))
```

 # Pre-Katrina (2004) specified models

```
library(lme4)
hosp <- read.table('hospitalization.txt', header=T, sep='\t')
hosp <- subset(hosp, hosp$Time == 2004)
hosp$BG <- as.character(hosp$BG)
hosp$Pop <- hosp$Pop2004
hosp$lPop <- log(hosp$Pop)

demog <- read.table('Demographics 2000_Used in Analysis.txt', header=T, sep='\t')
demog$STFID <- as.character(demog$STFID)
rownames(demog) <- demog$STFID

# Check variable consistency
all(hosp$BG %in% demog$STFID)
all(hosp$PCTWhite == demog[hosp$BG, "PCTWHITE"])
all(hosp$PCTBlack == demog[hosp$BG, "PCTBLACK"])
all(hosp$MedYrBlt == demog[hosp$BG, "MedYrBlt"]) # !!
all(hosp$HH2000 == demog[hosp$BG, "HH2000"])
all(hosp$MedHHInc == demog[hosp$BG, "MedHHInc"]) # !!
sum(is.na(demog[hosp$BG, "MedHHInc"]))
sum(is.na(hosp$MedHHInc))

# Merge
hosp$MedYrBlt <- demog[hosp$BG, "MedYrBlt"]
hosp <- data.frame(hosp, demog[hosp$BG, c("PCTAsian", "PCTMale",
```

```
  "MED_AGE", "AVE_HH_SZ", "MARHH_CHD", "FEMHH_CHILD",
  "VACANT", "OWNER_OCC", "RENTER_OCC", "HSE_UNITS")])
hosp$MARHH_CHD <- hosp$MARHH_CHD / hosp$HSE_UNITS
hosp$FEMHH_CHILD <- hosp$FEMHH_CHILD / hosp$HSE_UNITS
hosp$VACANT <- hosp$VACANT / hosp$HSE_UNITS
hosp$OWNER_OCC <- hosp$OWNER_OCC / hosp$HSE_UNITS
hosp$RENTER_OCC <- hosp$RENTER_OCC / hosp$HSE_UNITS
#  Note: VACANT + OWNER_OCC + RENTER_OCC == 1

hosp.mood <- subset(hosp, hosp$Disease=='Mood and Anxiety' & hosp$Pop > 0)
hosp.psychosomatic <- subset(hosp, hosp$Disease=='Psychosomatic' & hosp$Pop > 0)
hosp.abuse <- subset(hosp, hosp$Disease=='Substance Abuse' & hosp$Pop > 0)
```

Mood and Anxiety Hospitalizations Model

```
summary(m.orig <- glm(Count ~ MedYrBlt + PCTPOV + WaterDepth, poisson, hosp.mood,
offset=hosp.mood$lPop ))
summary(m.1 <- glm(Count ~ MedYrBlt + PCTPOV, poisson, hosp.mood,
offset=hosp.mood$lPop ))
summary(update(m.1, .~.+PCTAsian))
summary(update(m.1, .~.+PCTMale))
summary(update(m.1, .~.+HSE_UNITS))
summary(m.2 <- update(m.1, .~.+AVE_HH_SZ))
summary(update(m.1, .~.+AVE_HH_SZ+HSE_UNITS))
summary(m.3 <- update(m.2, .~.+MARHH_CHD))  # AIC 1605.821
summary(update(m.2, .~.+FEMHH_CHILD))
summary(m.4 <- update(m.3, .~.+VACANT))     # AIC 1603.5
summary(update(m.3, .~.+OWNER_OCC))  # AIC 1603.9
summary(update(m.3, .~.+RENTER_OCC))

summary(m.final <- glm(Count ~ PCTPOV + AVE_HH_SZ + VACANT, poisson, hosp.mood,
offset=hosp.mood$lPop ))
```

Stress Related Psychosomatic Hospitalizations Model

```
summary(p.orig <- glm(Count ~ Units2000 + PCTWHITE, poisson, hosp.psychosomatic,
offset=hosp.psychosomatic$lPop ))
summary(update(p.orig, .~.+PCTAsian))
summary(p.1 <- update(p.orig, .~.+PCTMale))
#summary(update(p.orig, .~.+HSE_UNITS))
summary(p.2 <- update(p.1, .~.+AVE_HH_SZ))
summary(p.3 <- update(p.2, .~.+MARHH_CHD))
summary(update(p.2, .~.+FEMHH_CHILD))
summary(update(p.3, .~.+VACANT))
summary(update(p.3, .~.+OWNER_OCC))
summary(update(p.3, .~.+RENTER_OCC))
```

```
summary(p.final <- glm(Count ~ Units2000 + PCTWHITE + PCTMale + AVE_HH_SZ +
MARHH_CHD, poisson, hosp.psychosomatic, offset=hosp.psychosomatic$lPop ))
```

Substance Abuse Hospitalizations Model

```
summary(a.orig <- glm(Count ~ PCTPOV + HHMAIL2005, poisson, hosp.abuse,
offset=hosp.abuse$lPop ))
summary(a.0 <- glm(Count ~ PCTPOV, poisson, hosp.abuse, offset=hosp.abuse$lPop ))
summary(update(a.0, .~.+PCTAsian))
summary(update(a.0, .~.+PCTMale))
summary(update(a.0, .~.+HSE_UNITS))
summary(update(a.0, .~.+AVE_HH_SZ))
summary(a.1 <- update(a.0, .~.+PCTMale + HSE_UNITS + AVE_HH_SZ))
summary(update(a.1, .~.+MARHH_CHD))
summary(update(a.1, .~.+FEMHH_CHILD))
summary(a.2 <- update(a.1, .~.+MARHH_CHD + FEMHH_CHILD)) # AIC 1647.556
summary(update(a.2, .~.+VACANT))     # AIC 1645.1
summary(update(a.2, .~.+OWNER_OCC))  # AIC 1646.6
summary(a.3 <- update(a.2, .~.+RENTER_OCC)) # AIC 1640.9
summary(update(a.2, .~.+VACANT + RENTER_OCC)) # AIC 1639.2

summary(a.final <- glm(Count ~ PCTPOV + PCTMale + HSE_UNITS + RENTER_OCC,
poisson, hosp.abuse, offset=hosp.abuse$lPop ))
```